AN ANALYSIS OF LEARNING CHARACTERISTICS, PROCESSES, AND REPRESENTATIONS IN MATHEMATICAL MODELLING OF MIDDLE SCHOOL LEARNERS WITH SPECIAL EDUCATIONAL NEEDS

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ABSTRACT

The special needs community is in the midst of a philosophical and physical shift from a segregated system to an integrated system, not only in placement, but more importantly, in terms of learning and affording learners with special needs access to mainstream curricular materials. Mathematical modelling, or challenging mathematics problems solved in small groups, is part of the Australian mainstream curriculum.

The purpose of the study was to investigate the way special needs learners learn mathematics from a modelling learning environment. To do this, it was necessary to identify the critical characteristics of the best practice in teaching and learning for learners with special needs, and the critical features of modelling. One theory of learning that has the capacity to promote special needs learners' interaction with mathematical modelling is Feuerstein's theory of Structural Cognitive Modifiability. A hypothetical learning trajectory was designed for special needs learners at middle school according to general design principles from theory, which was adapted to the learning characteristics of the class. The learning environment comprised of three challenging modelling tasks, together with recommended implementation and support conditions in the classroom. Specifically, the research sought to investigate the ways in which special needs educators can support the higher reasoning processes of special needs students during modelling through design in general, and through mediation specific to each learner. The research took the form of a qualitative study, combining the phases of design-based research with a multiple case study approach. Three cases were analysed in depth. Empirical data were collected through a range of qualitative methods, which included data from student files, field observations, video and audio recordings, focus group interviews with students, and the input of various collaborators across the different phases of planning, design, implementation, and revision. Data were coded and analysed inductively according to emerging patterns and themes. Findings suggest that the use of modelling was successful when implemented with certain characteristics defined in the literature, and that it enabled learners to learn mathematics and also to develop additional outcomes such as social skills and language. During this study, learners' higher-order reasoning was supported through dynamic assessment and subsequent mediation.

KEY WORDS: mathematics teaching and learning**,** mathematical modelling, special needs learners, middle school, design based research

'n Analise van leerkenmerke, prosesse en voorstellinge in wiskundige modellering van middelskool leerders met spesiale behoeftes.

ABSTRAK

Die onderwysgemeenskap vir leerders met spesiale behoeftes bevind hulle in die middel van filosofiese en fisiese verskuiwings van 'n geskeide sisteem na 'n geïntegreerde sisteem. Dit omvat die plasing van leerders, maar meer belangrik ook die bemoontliking van toegang van hierdie leerders tot hoofstroom kurrikulêre materiale. Wiskundige modellering, en uitdagende wiskundeprobleme wat deur leerders in klein groepies opgelos word, is deel van die Australiese hoofstroomkurrikulum.

Die doel van die studie was om die wyse te ondersoek waarvolgens leerders met spesiale behoeftes wiskunde in 'n modelleringsomgewing leer. Dit is gedoen deur die belangrike kenmerke van beste praktyk vir onderrig en leer in spesiale onderwys, asook die kritiese kenmerke van modellering, te vind.

Een leerteorie wat die interaksie van leerders met spesiale behoeftes met wiskunde bevorder, is Feuerstein se teorie van Strukturele Kognitiewe Modifieerbaarheid. 'n Hipotetiese leertrajek was ontwerp vir leerders met spesiale behoeftes op middelskoolvlak. Empiriese data is deur 'n reeks kwalitatiewe aksies: data van studenteleêrs, veldwaar-nemings, video en klankopnames, fokusgroeponderhoude met studente, asook die insette van verskeie medewerkers oor die verskillende fases van beplanning, ontwerp, implementering en hersiening gegenereer. Die spesifieke leerkenmerke van hierdie leerders volgens algemeen-teoretiese en lokaalgekontekstualiseerde ontwerpbeginsels is nagekom. Die leertrajek het bestaan uit drie uitdagende modelleringsprobleme met aanbevole implementering en ondersteuningsriglyne in die klaskamer.

Die navorsing het spesifiek gesoek na wyses waarop hierdie leerders se hoër beredeneringsvaardighede deur hul onderwysers, volgens elkeen se eie behoefte gedurende modellering, deur ontwerp in die algemeen en mediasie in die besonder, ondersteun kan word. Die navorsing, 'n kwalitatiewe studie, was gekombineer met fases van ontwikkelingsgebaseerde ontwerp wat uitgespeel het in 'n veelvuldige gevallestudiebenadering. Drie gevalle is in diepte ondersoek. Data was induktief gekodeer en geanaliseer volgens ontluikende patrone en temas. Bevindinge wys uit dat die gebruik van modellering suksesvol was wanneer die implementering volgens spesifieke kenmerke in die literatuur was. Dit het leerders instaat gestel om wiskunde te leer asook om addisionele uitkomste soos sosiale vaardighede en taal te ontwikkel.

In hierdie studie is hoër-orde denke ondersteun deur dinamiese assessering en voortspruitende mediasie.

SLEUTELWOORDE: wiskundeonderrig en leer, wiskundige modellering, leerders met spesiale behoeftes, middelskool, ontwikkelingsgebaseerde ontwerp.

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To Meg, for being there,

And my Heavenly Father, for His wonderful serendipity during this season of study.

DECLARATION

I, the undersigned, hereby declare that the work continued in this dissertation is my own original work and that I have not previously in its entirety, or in part, submitted it to any university for a degree.

December 2014

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LIST OF ABBREVIATIONS

ABA	Applied Behaviour Analysis
ACARA	Australian Curriculum, Assessment and Reporting Authority
DA	Dynamic assessment
DBR	Design-based research
DSM	Diagnostic and Statistics Manual
EAP	Education Adjustment Programme
ICTMA	International Conference on the Teaching of Mathematical Modelling and Applications
HLT	Hypothetical Learning Trajectory
IQ	Intelligence Quotient
LSA	Learner Support Assistant
NME	Neurosequential Model of Education
NMT	Neurosequential Model of Therapeutics
RtI	Response to Intervention
SEN	Special Educational Needs
SNE	Special Needs Education
UDL	Universal Design for Learning
UNESCO	United Nations Educational, Scientific and Cultural Organization
ZPD	Zone of Proximal Development

CHAPTER 1
BACKGROUND AND RATIONALE OF THE RESEARCH

1.1. BACKGROUND

Decades of research have confirmed the need for all learners to have access to quality mathematical teaching and learning. There is always the fear that reduced learning opportunities at school may lead to reduced life opportunities later on. Likewise, the archetype that mathematical concepts and skills are significant for "life-after-school" is well established in education. This thought frequently appears in all kinds of literature, rendering it simultaneously scientific and stereotypical. Though the premise may be true that knowing mathematics is necessary and beneficial to learners, the processes and mechanisms of learning mathematics are much more controversial. Since learning is in itself a psycho-educational concept that comes with freight attached, educators are still trying to determine those elements of instruction that are worthwhile adopting in the teaching and learning of mathematics. Equally important, and following on from these resolutions, is the kinesis of investing educational thought into the development of a philosophy or a paradigm that holds promise.

In this study, the difference of opinion as to which aspects of mathematics should be taught, which hold promise and which do not, weighs upon the affordance of mathematical modelling in school curricula. According to authors of modelling (Freudenthal, 1971, Blomhøj & Jensen, 2003, Doerr & Pratt, 2008) modelling is about interpreting and finding solutions to everyday life situations mathematically through building and testing models. A complex problem is placed in a culturally meaningful real-life setting. Learners work collaboratively[1] to identify the problem, imagine and implement a solution, and then evaluate and modify it through feedback. The primary objective is to use contextualised mathematics that are experientially real to learners and to generate formalised and decontextualised mathematical principles (Treffers, 1993, p. 94).

Mathematical modelling has been around since the invention of mathematics, but its

[1] The meaning of collaborative learning in terms of modelling is detailed in Chapter 3, Section 3.3.7

appearance in the classroom is relatively new. In his analysis, Burkhart (2006) provides an international perspective of the process of introducing mathematical modelling into mainstream school curricula. He identifies three periods: 1960 to 1980, 1980 to 2000, and 2000 onwards. From 1960 to 1980 there was a period that Burkhart refers to as a time of tentative exploration occurring in England, America, Netherlands, and Australia. The desire for change was partly stimulated by the worldwide movement towards reforming mathematics and their call for a more interactive rather than transmissive approach to teaching. It was also during this time that computers were being introduced into schools in pockets of the Western world. The period from 1980 to 2000 portrayed a move towards formalising the modelling movement by introducing international movements dedicated to modelling, such as the *International Conference on the Teaching of Mathematical Modelling and Applications* (ICTMA) established in 1981, in addition to a range of international workshops and conferences, and the development of coherent exemplar modelling curricula. Burkhart states that in the current period from 2000 onwards, modelling has had a relatively modest effect on mathematical teaching and learning worldwide, and that more work needs to be done to reach the large scale impact that is hoped for by it supporters. In Australia, modelling is included in the national curriculum, *Australian Curriculum, Assessment and Reporting Authority* (ACARA, 2013c) from Foundation Phase upwards. It is found under the problem-solving descriptor where it is noted that problem-solving, amongst other directives, includes the fact that learners need to use materials to model authentic problems and discuss the reasonableness of the answer.

1.1.1 Mathematical modelling and the special needs environment

It is important to realise that whereas modelling may be a legal requirement in Australia because of its position in ACARA, it has had almost no effect in the special needs sector, where it remains largely underdeveloped. Van den Akker (2010, p. 56) mentions how some education scenarios are marked by a substantial disconnect between the intended curriculum, the implemented curriculum, and the attained curriculum, where the intended curriculum expresses and contains the world of policy and design, the implemented curriculum the world of schools and teachers, and the attained curriculum the world of learners. This seems to be the case of modelling in Special Educational Needs (SEN) classrooms — permitted in policy and omitted in practice.

1.1.1.1 In policy, not in practice

With regard to classroom practice, most scholars in the field believe that explicit, direct, and systematic teaching of concepts are best practice in the field of special needs education, where each step is modelled by the teacher and then reproduced by the learner. For instance, meta-analysis researchers such as Kroesbergen and Van Luit (2003, p. 97) endorse the continuation of a behaviourist approach in the form of direct, explicit teaching in a scaffolded manner to learners with special needs. As a result, mediated-centred learning techniques are commonly not used for special needs learners in Australia. From Diezman, Stevenson and Fox's (2012) overview of the state of research around learners who are underperforming in mathematics in Australasia, we know that the focus so far has been on early identification and intervention and subsequent recovery methods (Diezman *et al.*, p. 99). Direct instructional approaches, such as the *QuickSmart* programme, have been associated with positive outcomes for learners with learning difficulties and for this reason are promoted with learners who are struggling with mathematics (Diezman, *et al.*, 2012, p. 101). Accordingly, Diezman *et al.* (2012), conclude that while "problem-based approaches are recognised as a valid method for teaching primary mathematics in current curricula (ACARA, 2013c), little empirical evidence has been generated from research to substantiate its use as an instructional approach for teaching learners with learning difficulties.... This significant gap in literature needs to be addressed..." (p. 100).

In addition to needing more research on learners with SEN and problem-solving, Diezman *et al.* (2012) showed that there is a need in Australasia "for more detailed attention being given to understanding the particular characteristics of learners and local school settings as influences impacting on programme implementation..." (p. 99). In other words, the impact of contextual factors on intervention needs to be understood.

1.1.1.2 In policy, not in research

Not only is there a gap between policy and practice, there is also a gap

> between research and practice. Internationally, research has been generated into mathematical modelling for a diverse range of cohorts and settings including but not limited to the gifted (Brandl, 2011), young children (English, 2004), and ethnic and linguistic minority groups from low socio-economic backgrounds (Boaler, 2008, p. 609). On the South African front, the concept of how learners learn through modelling started with the work of researchers like Hiebert *et al.* (1996). For the most part, there is little said on mathematical modelling for learners with special needs. An exception is the work of Van den Heuvel-Panhuizen and her doctoral learners (Van den Heuvel-Panhuizen, 2012, Peltenburg, van den Heuvel-Panhuizen, & Robitzsch, 2012) who since 2008 have been investigating the potential of special needs learners to manage a problem-centred approach.

Consequently, there is opportunity to extend the existing practice of mathematical modelling to a community of learners who are still largely unfamiliar with its practice.

1.2 STATEMENT OF THE PROBLEM

We know from an Australian review on special needs education, that learners with SEN make learning gains from direct instructional approaches (Ellis, 2005). Even so, the scarcity of reference to modelling in Australia's special needs sector is of concern. What should our response be as educators, seeing that its position in ACARA makes it part of the teaching load? Specifically, how should we approach modelling, granted that modelling is a challenging form of mathematics and learners with SEN typically have significant learning difficulties?

I suggest that we restrain our inclinations to deal with diversity by excluding learners from certain educational experiences. Given that, we engage with modelling as a practical possibility for all learners without trying to circumvent or suppress the obvious challenges emerging from this type of instruction with learners with SEN. That is to say, I concede with Nordenfelt (2010) that “practical possibilities for people with disabilities depend on a *supportable* (my emphasis) interrelationship between opportunity and ability” (p. 52). In the context of this study, I refer to ability as an entity with growth potential, and like a growth point is not fixed, but having the capacity for change. The emphasis of my own position in the debate is on the notion of "supportable".

1.2.1 Instructional design to support learners with SEN

I am positive about modelling as a learning option for learners with SEN in spite of its foreseeable challenges. Nevertheless, a key point is that learners with SEN may require extraneous support and educators should adapt and readapt the approach with that support in mind. On the whole, I see the way forward through designs where the elements of their successes are critically connected to the challenges of providing suitable support.

There are two aspects from literature that will inform my attempt to design modelling tasks forl.

1.2.1.1 Developing transparent solutions

A criticism that emerged from within disability discourse is the outcry that abled people are misrepresenting the non-abled by abridging who they are (Silvers, 2010, p. 33). For this reason, researchers must take care to reflect accurately who people with disabilities are within their context, including their experiences, priorities, and needs. Accurate representation depends on differences between people being *addressed* instead of being suppressed. The assumption from this criticism is that we should admit that learners with SEN face significant challenges when it comes to their learning. With this in mind, the goal is a balanced outcome, not ignoring differences nor making them the only point of focus while working towards solutions. For this reason, the design process needs to be honest and transparent in cultivating strengths and in supporting vulnerabilities and/or dysfunctions as well, yet at the same time be protective of the learners' dignity and sense of self-efficacy.

1.2.1.2 Working towards inclusive practice

The second aspect influencing the nature of this study is the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2005, p. 15) elements for inclusion. They are restated in Black-Hawkins's (2014, p. 391) framework for participation and suggests that there are four objectives towards inclusive practice. These are access, collaboration, achievement, and diversity. *Access* focuses on the learners being there for the activity, and more importantly in this context, the activity being there for the learners; *collaboration* captures the idea of learning and working together; *achievement* presses home the need that the activity is about learning; and, *diversity* monitors processes of and barriers to participation that are experienced by learners.

There is a natural synergy between the objectives from the framework of participation and the intended aims of this study. On the whole, modelling actualises the framework's principles of collaboration and achievement in so far as modelling is about small groups of learners working together on challenging maths problems as a way to learn worthwhile mathematics. Likewise, supporting learners with SEN in their modelling realises the framework's objective of diversity, since it implies addressing their barriers to participation in modelling.

Consider the present educational situation against the framework for participation:

- Modelling is not a common instructional task for learners with SEN — limited access.
- Learners with SEN are typically taught through direct instruction — limited collaboration.
- Learners with SEN, by nature of their category, tend to have significant learning difficulties — limited achievement.
- Learners with SEN experience a range of barriers — high diversity.

For most part, I concur with Black-Hawkins's (2014) notion that “the best way to increase participation in an activity is to reduce barriers to participation, and that the best way to reduce barriers to participation is to increase participation”

(p. 397). Accordingly, to secure inclusive practice for learners with SEN in mathematics, I propose starting with the fourth objective, which is addressing diversity, and use our efforts in this regard as a bridge towards accommodating the other three outcomes. With this in mind, we start by identifying the barriers in terms of access, in terms of collaboration, and in terms of achievement.

i) Securing access for diverse learners:

The first barrier to overcome is the exclusion of learners with SEN from modelling tasks. Dai (2012, p. 196) reminds us that we need to be careful as educators to not exclude learners from opportunities like modelling on the basis of how "smart" we estimate the learners to be. Instead, we should focus on how "smart" our instructional design is. The basis of Dai's thinking is a much larger debate in psychological circles on whether development is a prerequisite for modelling, whether modelling is development, or whether modelling can be used for development. In the first instance, as educators we could argue that learners with SEN have not developed the higher-reasoning processes needed by modelling, and therefore modelling will not prove useful to them. In the second instance, we assume that as learners do modelling they will learn mathematics at the same time, provided that the modelling tasks match their actual developmental level. In the third instance, we anticipate that learners with SEN are generally not ready for independently learning mathematics through modelling. Yet, we still model, in the conviction that modelling with a more knowledgeable other becomes the tool for developing and strengthening the cognitive and social processes and functions of these learners, and in the hope of activating learning through modelling as a result. I approach this study from the latter framework, using modelling to develop the necessary processes in learners. My intent in the matter is not to get caught up in the current state of the learners by waiting for development before teaching but to take the learners further by teaching for development instead.

ii) Securing collaboration for learners with SEN:

Some learners may need additional support with social processes and with negotiating the interpersonal dimensions of modelling. Their required level of support in these matters will depend on their respective strengths and vulnerabilities as per their profiles. These processes will be supported in this study through explicit teaching, imitation, and reflective conversations with the learners.

iii) Securing learning for learners with SEN:

Modelling relies on higher-order cognitive processes. The form and nature of higher-order processes are still being debated. If we use Resnick's (1987b, p. 3) list we have a great fit with modelling. Resnick suggests thathigher order processes are non-algorithmic (action is not fully specified in advance); complex (the total path is not mentally visible from a single perspective); and, that these use nuance, meaning, interpretation, varied criteria, effort, and uncertainty to arrive at multiple solutions.

This study starts with the premise that forms of higher reasoning processes are likely to be vulnerable and underdeveloped in learners with SEN. With this in mind, Feuerstein's theory of *Structural Cognitive Modifiability* (Feuerstein, Rand, & Rynders, 1988; Feuerstein, Feuerstein & Falik, 2010, p. 13; Feurerstein, 2013) is applied to the premise. In his framework, Feuerstein is well aware that learners with SEN typically have poor thinking skills and approaches it as follows: First, he specifies that poor thinking, reasoning and problem-solving are related to cognitive deficits in learners with SEN. Second, he suggests that these cognitive deficits be identified and strengthened through mediation. Third, he argues that by addressing the cognitive deficits we bring about structural changes in cognition. These structural changes serve to support further learning experiences.

From Feuerstein's work, we can use the concept that mathematical modelling content and processes will need to be supplemented with the mediation of specific cognitive functions. To this end, I believe that modelling provides a natural environment to help learners not only acquire mathematical knowledge but, more importantly, to acquire psychological tools that allow for the acquisition of mathematical knowledge.

Likewise, from Black-Hawkins's (2014, p. 396) work we can anticipate that the support needs of the same individual will likely be shifting, and that support is a very individual, even idiosyncratic process where the kind of support intended for one individual may reinforce barriers for another. For this reason, Black-Hawkins cautions that the ideal of full participation in classroom setups, and in this instance in modelling activities should not necessarily be viewed as a state to be achieved but as a series of ever-shifting processes that require careful attention.

In the light of the push for inclusive educational practices, the intentions of this study are neither capricious nor careless towards the well-being of learners with SEN. Similar sentiments are found internationally. For example, the National Education Standards in Europe is moving in a new direction by recognising the following needs (Linneweber-Lammerskitten & Wälti, 2008):

- It is necessary to find better ways to deal with heterogeneity — especially to provide more support for weaker pupils.
- It is necessary to give more attention to the non-cognitive dimensions of mathematical competency, such as motivation, sustaining interest, and the ability to work in a team.
- It will be necessary to deal with aspects of mathematical competence that were mostly neglected in the past — especially the ability and readiness to explore mathematical states of affairs, to formulate conjectures, and to establish ideas for testing conjectures.

1.3 AIMS OF THE STUDY

1.3.1 Local Theory of Instruction

This study is about creating a set of modelling tasks for a local SEN classroom for the purpose of using data generated by the setting to improve my own pedagogical practice in this regard. Considering the challenges that learners with SEN face, the interactions between the design and the learners were unpredictable at the outset. It was hoped that the design would affect the participants' learning of mathematics and that the response of learners with SEN to the design would in turn improve the understanding of educators and researchers as to how to approach modelling tasks in this context. As was noted earlier, interpretations and interventions from within a particular context shape both the original design and influence the intended outcomes. To this end, the innovation was flexible and continuous adaptations, including undesired mutations, were expected and studied as sources to improve the design and to contribute to theory. Since the design is a local theory of instruction, it embodies what is relevant and meaningful to local use and promotes local capacity, ownership, and development. Accordingly, I consider this research and its analysis as the basis of a self-review framework through which I can reflect on and improve my practice.

The focus in designing a local theory of instruction is on producing research that is useful. Usefulness lies on two planes. Whereas one level has to do with finding a workable intervention or prototype that is continually moving towards the ideal, the other level concerns drawing out general design principles that are scientifically sound to support both theory development and future prototype evolution (Van den Akker, 1999, p. 9; Anderson & Shattuck, 2012, p. 16). To clarify, the real usefulness of design-based research (DBR) is its potential to improve learning, both at a pragmatic level and a theoretical level (Herrington, Reeves & Oliver, 2010, p. 3959 Kindle edition). The theory that I associate with this study is *the Social Constructivist* theory, also known as the cultural-historical orientation. With regards to the Social Constructivist framework, I put specific emphasis on Feuerstein's theory of Structural Cognitive Modifiability as an application of Vygotsky's (1978b, p. 86) notion of emergent cognitive functions being strengthened through joint activity in the Zone of Proximal Development (ZPD).

1.3.2 Contributing to Socio-Constructivist Learning Theory

In working from a Vygotskian perspective, I propose that the modelling phases resemble the Zone of Proximal Development (ZPD) space, where learners' development is being pulled along through peer and adult mediation in the context of joint activity. According to Vygotsky, two very important processes happen in the ZPD, namely immature and emergent mental functions are strengthened and the everyday and intuitive concepts of the learner meet the scientific concepts of the subject domain.

Vygotsky's (1978b) notion of strengthening emergent mental functions and Feuerstein's work on strengthening weak cognitive deficits are essentially the same. It is important to remember that as much as Feuerstein was a protégé of Piaget at the Geneva Institute, his work is generally considered to be more in line with Vygotsky. To explain, I use Kozulin's (2013) comparison of Piaget, Vygotsky and Feuerstein as the key conceptions of how learning occurs. Whereas Piaget suggested that learners learn through direct interaction with the environment (curricula), Vygotsky proposed that learners learn through mediation with psychological tools and that they respond through psychological tools. In other words, Vygotsky placed psychological tools between the child and the environment. A key point to remember is that Feuerstein's work is almost identical to Vygotsky's except that he replaces psychological tools with human mediation alone, meaning that in his view it is only humans who will effectively mediate between a child and his environment. A comparison of Piaget, Vygotsky, and Feuerstein's view of learning is found in Table 1.1.

Table 1.1 Comparing Piaget, Vygotsky and Feuerstein's notion of learning

Theorist	**Theoretical orientation**	**Applied to Modelling**
Piaget	material - learner - response	maths problem - learner - model
Vygotsky	material - psychological tools - learner - psychological tools - response	maths problem - tools (material, symbolic, humans) - learner - tools - model
Feuerstein	material - mediator - learner - mediator - response	maths problem - teacher/peer - learner - teacher/peer - response

Table 1.1

These processes are not necessarily mutually exclusive. For example, human mediators provide psychological tools, and as the learners' psychological functions are strengthened, they become more able to interact directly with materials outside of mediation.

Furthermore, the similarities in ideas between Vygotsky and Feuerstein are apparent in their work on how to develop higher order processes in a learner. For this reason, Miller (2013) concludes that "Feuerstein's work on Mediated Learning provides an outstanding example of the application of Vygotsky's ideas" (p. 7). Kozulin (2014) expands on Vygotsky’s view of cognitive work in the ZPD:

> Vygotsky (1935/2011) argued that typical psychological studies focus only on those psychological functions that have already fully matured and as such are displayed by children in their independent activity. By suggesting an analogy with a gardener who is expected to foresee the development of his crop already at the bud and flower stage, Vygotsky pointed out the need to study those emergent mental functions that have not yet matured. The way to identify these emergent functions is to engage the learner in joint activity with adults. In the context of such joint activity, the learner reveals some of the functions that are not mature enough for independent performance, but are already 'in the pipeline'. This model is based on the assumption that children's functions first appear in the joint activities of children and adults and only then are they internalized and transformed to become inner mental functions. Education is a source of the child's development rather than just a supplier of content knowledge that can be absorbed by the child with the help of already existent psychological functions. Curriculum should be closely analysed for its development-generating potential. (p. 554)

It is important to realise that Feuerstein, like Vygotsky, supports the notion of emergent functions, which are not yet mature enough for independent performance, but are in the pipeline. Feuerstein refers to the emergent functions as cognitive deficits. Consequently, an important aspect of teaching is developing these processes in learners.

1.3.3 Contributing to inclusive practice

Essentially, the aim of the project is to contribute to the fledgling discourse on mathematical modelling in SEN settings and to begin the process of collecting empirical data towards the articulation of its complexities and the consequent development of systematic practice in this field. The practical and theoretical gaps between policy, research, and practice leave the question unanswered whether mathematical modelling in a special needs environment is nothing but an idealist's chimera or whether it has something more substantial to offer this cohort of learners. In the case of modelling, there is not yet enough said to make scientific judgements as to whether modelling advances or hinders the mathematical learning of learners with SEN. In this event, it becomes difficult to scientifically justify either decision to withhold modelling tasks from learners with SEN or to incorporate modelling into their learning. For this reason, I am reviewing the *aspects of mathematics* that are most relevant to learners during the compulsory years of schooling, granted that certain learners have special educational needs. Yet, such a review cannot be made unless there is clear evidence demonstrating learning (or the lack thereof) during modelling tasks.

Data from my previous research project (Scott-Wilson, 2010), suggested that modelling developed a sense of well-being in the learners in that study. After initially resisting the move from a direct instructional approach to modelling, the learners' levels of interest, engagement, and enjoyment of the activities seemed to increase during the study. At the end of the study, the learners indicated that they preferred modelling as a teaching method over the more direct approach that was previously used in their class. The finding that modelling increases a sense of well-being in learners is collaborated by other international research projects (Schoen, 1993; Boaler, 1998; Riordan & Noyce, 2001; Clarke, Breed & Fraser, 2004). In terms of my own professional development, authors such Ecclestone and Hayes (2008) admonish educators that the well-being/therapeutic agendas are not sufficient measures of education, and that educators first and foremost have to account for the learning of learners. In other words, it is not sufficient to only note the positive attitudes developing in learners towards mathematics alongside the introduction of modelling activities. It is necessary to demonstrate that learners with SEN are actually learning from modelling.

With this in mind, the next step in my research was to examine how modelling contributes to expanding and enhancing learners' knowledge, skills, and value sets. In this study, I investigated whether learners with SEN stand to benefit from modelling tasks designed for them by analysing an instructional setting to see what evidence (if any) it yields to support the notion that they are learning mathematics from modelling tasks. Yet, as was explained earlier, there is another dimension to the study, that is, the strengthening of cognitive functions necessary for higher-order reasoning needed in modelling, which is in addition to the learning of mathematics.

1.3.4 Contributing to policy and practice

Findings from this research can strengthen the relationships between curricular research, policy, and practice by generating descriptions on how learners with special needs develop mathematically in terms of their reasoning processes and representations. It could also provide suggestions on how to deal with some of the more challenging characteristics that learners with SEN might display during modelling. Moreover, these types of research findings could aid the professional development of teachers by promoting capacity-building knowledge around the planning and performing of curricular designs for mathematical modelling in a special needs context, with the purpose of helping educators like myself become better teachers of learners with disabilities.

1.4 RESEARCH QUESTIONS AND TASK ANALYSIS

My intention was to add science to the speculation of how viable mathematical modelling is as an instructional addition or alternative for learners with SEN. To do so I needed evidence to show that learners with SEN are benefiting from modelling. Simply put, are they learning, and are they learning mathematics of the kind that is socially acceptable and institutionally sound?

The primary research question of the study is: *"How can mathematical modelling be used with learners with SEN to improve their understanding of mathematics?"*

To answer the primary research question, I divided the study into a series of sub-tasks with secondary research questions attached to certain of these tasks:

- How do the learners' characteristics, taken from their psycho-educational profiles, affect their modelling?
- How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?
- What evidence of learning could be found in the analysis of learners' reasoning and representations over time?
- How did the learners' learning correspond with the proposed learning trajectory?
- To what extent did modelling benefit and/or impede the mathematical learning of learners with SEN? An evaluation of the design against Tyler's (2013) general learning principles.
- How viable is modelling as an instructional approach in a SEN classroom based on an **analysis of learning characteristics, processes, and representations in mathematical modelling of middle school learners with special needs?**

1.4.1 Task A: Define the critical characteristics of learning environments for learners with SEN to access common core curricula

The ideal of education-for-all is not new, but its realisation in practice is an ongoing pursuit towards optimisation. The first stage of the research was to conduct a literature review of the existing knowledge base to identify the critical characteristics of a learning environment considered suitable for the instructional needs of learners with SEN. Simply put, what do learners with SEN need from instruction to support their learning? With this in mind, I examined pedagogical discourses generated by general education, inclusive education, and SEN domains. First, I considered the influence of disability models in bringing about inclusion. Second, I critically reviewed current pedagogical strategies in place to support and advance inclusion. Third, as this study is concerned with how learning happens in a SEN environment, I analysed the contributions of psychological theories of learning to inclusion. Last, I explained Feuerstein's theory of Structural Cognitive Modifiability, its commonalities and contrasts to current inclusive practices, and its suggestions for restoring learning in an inclusive environment.

1.4.2 Task B: Define the critical characteristics of modelling as an instructional task and analyse it as an option for SEN classrooms

In this section, I analysed the core components of modelling tasks from literature and critically evaluated their suitability for learners with SEN. I also propose that Feuerstein's list of cognitive deficits is the proverbial missing link between modelling and learners with SEN and discuss how these cognitive deficits can be strengthened through mediation in the context of modelling. In Figure 1.1 I depict my intention to bridge inclusive practices and modelling with the work of Feuerstein.

1.4.3 Task C: Establish the specific strengths and vulnerabilities of the research cohort

The third level of analysis was more personalised and unique to the learners themselves. It involved consulting the participants' school files to build a psycho-educational profile of each learner and his/her strengths, vulnerabilities, and required support. The elements identified in this phase of the study provided a framework for thinking about the design, specifically in terms of which type of support (if any) would be necessary and at what level of instruction the mathematical concepts should be pitched

1.4.4 Task D: Designing the hypothetical learning trajectory

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I used information from Tasks A to C to design a hypothetical learning trajectory (HLT) with tasks in mind that are age-appropriate, developmentally appropriate, and culturally sensitive. The tasks were for implementation in a SEN classroom in a state middle school.

Figure 1.1 Bridging inclusive pedagogy and modelling with Feuerstein

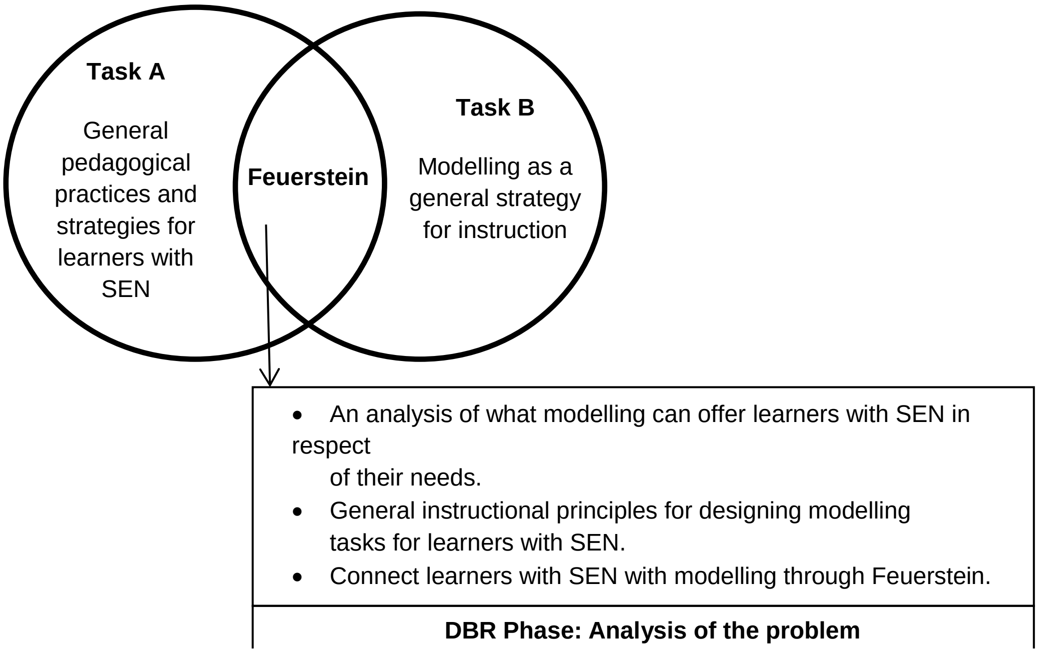


Figure 1.1

1.4.5 Task E: Pre-Evaluation: Screening, Co-Teaching, and Tryout of Approach (not activities), Practitioner Consultation, Consultation with Cultural Advisor, Expert Consultation

Moreover, the information provided in this stage of the study enabled further refinement of the modelling tasks as well as the refinement of the methodology used for Task E of the study. With this in mind, several measures were taken to determine the feasibility of the proposed research design and to begin the process of developing a classification scheme to analyse the learners' response to the designs. The measures involved screening the tasks against assessment criteria from literature. I also arranged to co-teach the intended class with an experienced colleague from another SEN unit. Together, we trialled some of the features of the approach (not the actual activities) in Social Science and English by letting learners present projects and give and receive feedback to one another on these projects. Thereafter, we reviewed the proposal together, its intended tasks, its instruments, and its methodology in relation to the needs of the learners. After this event, I invited a Student Services Advisor to conduct a review of the suitability of the modelling tasks. Likewise, I invited a cultural advisor to sit in on the teaching sessions to monitor the instructional practices, the classroom environment and routines, and to analyse the tasks I intended to use in the upcoming study for cultural sensitivity and appropriateness. Figure 1.2 depicts how Tasks C, D and E combine in this study.

Figure 1.2 Developing a localised HLT for learners with SEN through collaborative evaluation

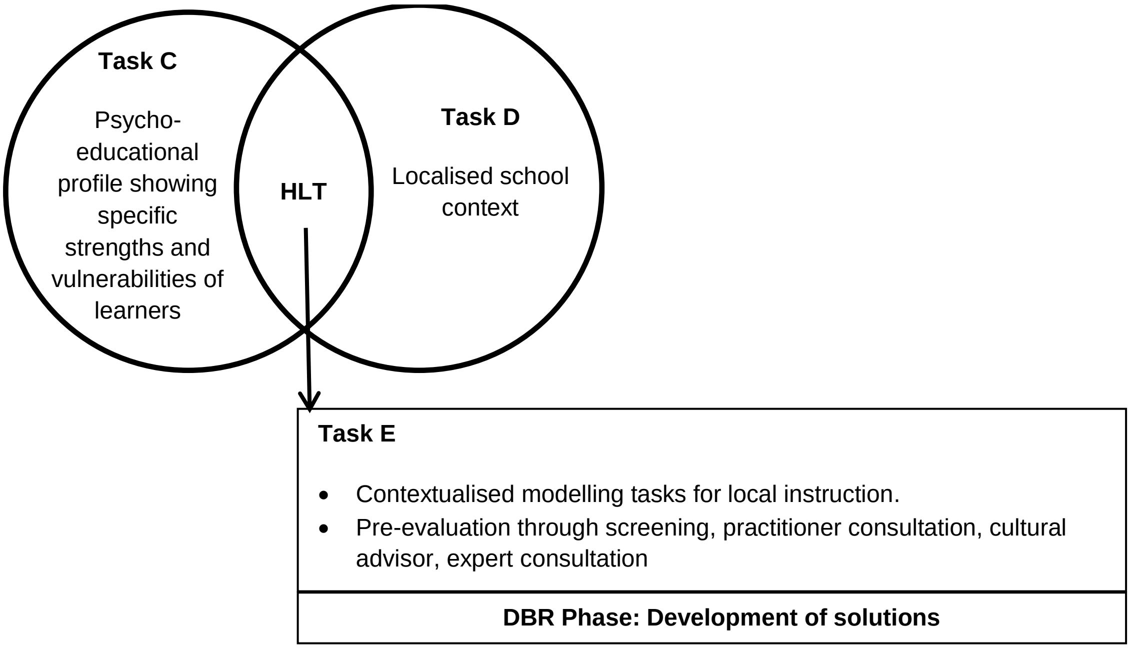


Figure 1.2

1.4.6 Task F: The implementation of three modelling tasks in a SEN classroom

The intention of this part of the study was to teach mathematics using modelling tasks informed by the Australian Curriculum framework. This part of the study examined learners' responses to the design in their normal classroom environment, with a particular interest in their use of Feuerstein's cognitive functions.

For this reason, learners were given three challenging modelling tasks, which they had to solve by working through the cycles of modelling in small groups.

My own role was as teacher-researcher. During the lessons, I worked with the participants while investigating their learning and their responses to elements of the instructional settings, with the purpose of identifying affordances and constraints that emerged, which may aid or hinder their achievement of the intended learning outcomes, and by considering how to overcome these through mediation.

After each challenge, I went through a process of reflection, collaboration and refinement before the implementation of the next cycle of modelling in the form of a new maths challenge for the learners. (Herrington, McKenney, Reeves & Oliver, 2007, p. 4-5). It was necessary to analyse the learning characteristics, processes, and representations of the learners in response to the tasks implemented. Consequently, the following three research questions were attached to Task F:

- How do the learners' characteristics, taken from their psycho-educational profiles, affect their modelling?

- How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?

- What evidence of learning could be found in the analysis of learners' reasoning and representations over time?

1.4.7 Task G: Reflection

This part of the research focused on evaluating the programming by conducting an audit to generate data on how the design evolved and the degree to which general learning principles were actualised. For this purpose, the following two research questions were included in the study:

- How did the learners' learning correspond with the proposed learning trajectory?
- To what extent did modelling benefit and/or impede the mathematical learning of learners with SEN? An evaluation of the design against Tyler's (2013) general learning principles.

1.4.6 Task H: Preparing for publication

The final secondary research question was necessary to create a reasoned response to the value of modelling in the local context of the study and the value of the design for informing general theory.

How viable is modelling as an instructional approach in a SEN classroom based on an **analysis of learning characteristics, processes, and representations in mathematical modelling of middle school learners with special needs?**

Figure 1. 3 The implementation, evaluation and refinement of the modelling process towards generalised design principles

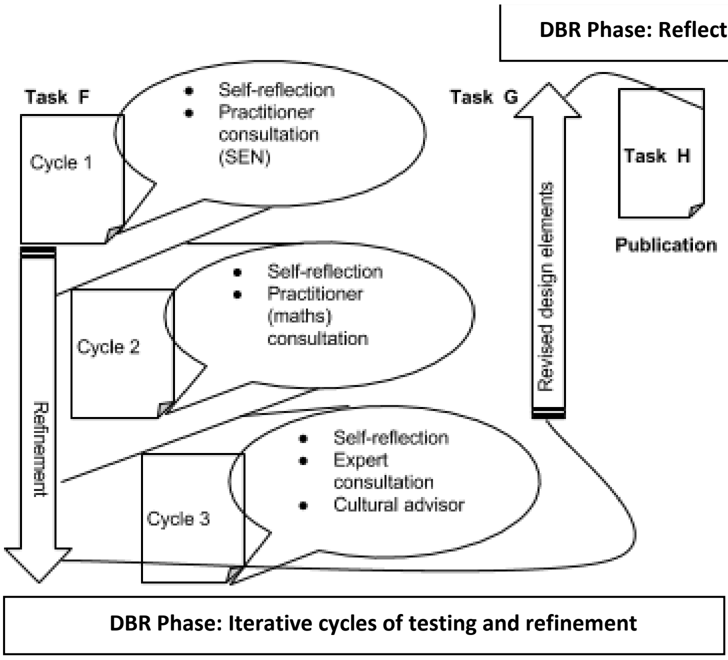


Figure 1.3

The last research question evaluates the viability of modelling as an instructional approach for learners with SEN by examining its potential for local use and for informing theory. Figure 1.3 depicts how the evaluation of the viability of modelling began with the process of modelling challenges being implementation in Task F, an evaluation in Task G, and a reflection of its value in the form of completed study for publication in Part H.

1.5 METHODOLOGY

In the final analysis, the aim of the research is modelling-for-all by designing lessons to support more vulnerable or weaker learners. Equally important is the intent to cultivate design principles that will culminate in increasing levels of sophistication in how teachers respond to this cohort of learners' needs during instructional situations that use modelling. I see two processes as salient to this study, namely, designing and describing. Accordingly, this study will use design-based research (DBR) as its primary research vehicle and a multiple-case study approach as it second research methodology.

Whereas the design-based research will capture the cycles of the design, its planning, its implementation, and its evaluation, a case study approach will cover the descriptive part of the study. Merriam (2009) notes that the case study approach will allow for "rich descriptions and analysis in a bounded setting" (p. 40), while Kelly (2003) argues that the design-based perspective produces “operative dialogue “ (p. 3) on mathematical modelling in a SEN environment.To clarify, design-based research is "use" orientated — it works towards developing a model of how mathematical modelling tasks can be developed, enacted, and sustained within a special needs environment, while the case study approach allows for detailed documentation of the complexities, subtleties, nuances, and contextual factors that affect the designs. For this reason, the case study approach was used to provide data on the progression of the design with a careful mapping of how three learners with SEN engaged with and explored mathematical problems and established mathematical ideas in relation to a scientific learning trajectory. The three cases refer to a learner with autism spectrum disorder, a learner with developmental delay, and a learner with foetal alcohol spectrum disorder, respectively. On balance, when combined, these two processes of design and rich descriptions provided a body of knowledge on how learning occurs in a modelling context in a SEN setting. Table 1.2 shows the comparative roles of DBR and the case study methodology as used in this study.

Table 1.2 Comparing the roles of DBR and case study

Role of DBR	Role of Case Study
Design for support: Using principles from literature **Adjust design to support:** Through cycles of planning, implementation, and evaluation **General design principles:** Draw out general design principles to inform theory and practice	**Rich description of:** **Characteristics of learners:** Analyse dimensions of the psycho-educational profile, its influence on learning in modelling situations **Processes of learners:** Analyse how Feuerstein's cognitive functions influence their models **Representations of learners:** Analyse their representations as evidence of learning

Table 1.2

Qualitative data collection methods are used. Wolcott (2009) believes that, "There is no longer the need to defend qualitative research or to offer the detailed explication of its methods that we once felt obligated to supply"(p. 25). The logic of qualitative data collection methodology suits several basic features of the study: namely, that progress in individual learners were described and monitored; that data were monitored as it occurred across time rather than at the beginning and end of the study; and, that systematic visual inspection was the primary analyses of the intervention effects (adapted from Odom & Lane, 2014, p. 376). In Table 1.3, I show the connection between the Index of Inclusion, the development of the study, the role of the tasks in the study, and the phases of DBR.

Table 1.3 Showing how the Index of Inclusion is worked out in the study

INDEX FOR INCLUSION PROCESS (Booth & Ainscow, 2002)	**APPLICATION IN THIS STUDY**	**TASK**	DBR STAGES
PHASE 1: GETTING STARTED			DBR Stage 1: Exploration of the problem
Setting up and co-ordinating group	Enrolled at University with supervisors		
Reviewing the approach Exploring existing knowledge	Literature review	A B	
Deepening the inquiry	Researched proposal		
Preparing to work with other groups	Located suitable school for research Attended international workshops		
PHASE 2: FINDING OUT ABOUT THE SCHOOL		C D E	DBR Stage 2: Development of solutions informed by existing practices
Exploring the knowledge of staff and governors	Adopted a teacher-as-researcher role Was observed for six lessons by colleagues while teaching modelling tasks with learners Delivered presentation to panel on modelling as an instructional approach for feedback Co-taught with colleagues Liaised with disability advisor to schools		
Exploring the knowledge of learners	Taught the class for one term before designing tasks for them Drew up a psycho-educational profile of the learners based on information in their files, to decide which features of the design to prioritise		
Exploring the knowledge of parents/carers	Built relationships with parents/carers through school activities such as EAP meetings, phone calls, parent-learner evenings, and class morning-teas		
Exploring the knowledge of members of local community	Asked a community elder to be my cultural advisor		
Deciding priorities for development	School: Visible Learning Disability advisor: - Universal Design for Learning, development of higher order thinking, integrated practice Cultural advisor: Indigenous cultural norms Learners: Maths is boring – change it		
STAGE 3: PRODUCING AN INCLUSIVE SCHOOL DEVELOPMENT PLAN			
Putting the framework and its priorities into the school development plan	Aligned tasks with school's curriculum plan for the term. Location was the learning strand for the first 5 weeks of term		
STAGE 4: IMPLEMENTING THE PRIORITIES		F	DBR Stage 3: Iterative cycles of testing and refinement of solutions in practice
Putting the priorities into practice	Implemented it into my classroom with learners with SEN for 4 weeks as part of their typical mathematics routine, as per their timetable		
Sustaining development	Considered how barriers to participation can be removed by applying Feuerstein's principles to strengthen reasoning processes in learners Provided additional support for social processes		
Recording Progress	Qualitative data collection methods: interviews, samples of learners work, observation, field notes, video and audio-recordings		
STAGE 5: REVIEWING THE PROCESS			DBR Stage 4: Reflection to produce design principles and enhance solutions
Evaluating the process Reviewing the work Continuing the process	Analysed the data Collated themes Discussed themes in relation to research question Drew out general design principles to inform theory	G H	

Table 1.3

1.6 DELINEATION AND LIMITATIONS

1.6.1 Delineating the research cohort

The first delineation concerns the definition of special needs learners. The concept of learners with SEN are very broad indeed. The varied definitions of learners with learning difficulties in mathematics used in research make it difficult to form conclusions about mathematical learning.. For example, it was noted by Diezman, Stevenson and Fox (2012, p. 97) that there is not a clear enough distinction between terms such as learning difficulties, learning disabilities, mathematical learning difficulties, special education needs, low achievement, at risk, and other similar terms in policy documents to provide a coherent research picture (Diezman et al. p. 96). For the sake of this study, special needs learners will be confined to a small sub-category, namely the category of learners who are assigned a place in the special needs education centre. According to the current policy laid out in the *Enrolment of Students with Disabilities in Special Schools and Special Centres* (Section 1.3) (Department of Education and Child Services, 2012), the following criteria are relevant at Middle School:

- significantly below average intellectual functioning (Intelligence Quotient (IQ) of 70 or below on an individually administered IQ test), and
- concurrent deficits in adaptive functioning (functioning in the bottom 2% in areas such as communication, self-care, social/interpersonal skills, functional academic skills, work, health and safety) with multiple needs, and
- requiring intensive support for needs and a highly individualised program to allow access to, and participation in, the curriculum.

Learners who meet these criteria are allowed a place in a special education centre at middle school level on the basis that the parents/guardians provide consent. In saying this, there is some leeway in applying these criteria to learners and their families. For the purposes of this study, only learners who are currently enrolled in a special education centre will be included in the research. The definition of special needs in this paper is therefore limited to learners who meet the departmental criteria for a place in a special needs centre at middle school level and who are currently enrolled at and attending such a centre.

1.6.2 Localised and personalised knowledge structures

A particular limitation of the study concerns the generalizability of results. As was noted earlier, the context of this research project is the application of mathematical modelling tasks at grassroots level and a description of the accompanying localised adaptations that were required. Trying to design curricula for learners with SEN will be different in nature to designing curricula for mainstream classes in so far as SEN classrooms have a much stronger personalised focus, which are typically articulated through individualised learning plans and learning goals. Consequently, more attention is given to local knowledge structures when designing curricula. In this context, localised adaptations typically imply adjustments made that are appropriate for particular individuals with principles that may or may not be transferable to a wider, general cohort.

1.6.3 Learning and Dynamic Assessment

Learning in this study is described, operationalized, and evaluated through the lens of dynamic assessment. The reason for using dynamic assessment (DA) is that it is the approach that was used and recommended by Feuerstein and Vygotsky. Using it in this study establishes a sense of congruence between research theory and research practice. Tzuriel (2000) defines DA as "an assessment of thinking, perception, learning, and problem solving by an active teaching process aimed at modifying cognitive functioning" (p. 386).

Tzuriel (2000, p. 385) presents several reasons why it is good to use DA:
He argues that, on the whole, studies show that DA is more accurate in reflecting children's learning potential than static tests, especially with minority and learning disabled learners. There are several reasons for the variance between static tests and dynamic assessment in respect to learners with SEN. For example, learners with SEN often have difficulty understanding the language and requirements of testing situations, which hampers their test scores. Testing can also be anxiety-provoking for them. Moreover, the test results themselves describe learners in general terms, mostly

by referring to their position relative to their peer group. At the same time, testing says very little about the learners themselves — their learning, their cognitive functions, and their response to teaching. Different learners can have the exact same test score but arrive there through very different paths. Consequently, (Le Beer, 2011, p. 109–110) concludes that DA is more suitable than standardised testing:

- to find out about learning potential
- to explore underlying problems
- to explore the link between cognitive, emotional, motivational, and other factors
- to explore the influence of context, attitude, way of interacting
- to find out about how an individual functions in regular and optimal conditions
- to find out the kind of support that is needed to make the individual function

Not only does the DA approach have different goals to a standardised approach, it also uses non-standard instruments. Lauchlan and Carrigan (2013, p. 26) describe how DA can be operationalized. The suggested approach is to draw up a checklist of cognitive skills or learning principles, to work with the learner in a collaborative approach, to see which cognitive skills need strengthening, to teach or mediate for these, and then observe if any change has taken place. Lauchlan's description is the approach that will be followed in this study.

1.6.3.1 Dynamic Assessment and the timeline of the intervention

In this study I have deliberately reduced the timeframe of the research during its implementation phase in the classroom. One month is short for a researcher, but it is relatively long and demanding for a learner with SEN, considering that these learners typically tire more easily and that changes in routine by introducing research can be stressful for them. Moreover, as there is little said about modelling, should the evidence suggest that they do not learn successfully through modelling, a month is a long time to lose out on education for any learner, and even more so for learners with SEN who typically learn at a slower rate than their mainstream peers. An added benefit to using DA is that it can say a lot about a learner in a relatively short space of time. It eliminates the need to pre-test, teach over a substantial period of time, then post-test. Teaching-assessing-learning all take place at once. Consequently, there isn't any need to teach over an extended time frame before evaluating learning. It is important to realise that from a DA point of view, data are not necessarily compromised because of time span. During DA, the assessor continually collects data on the cognitive functions, how they were addressed, and how the learner responded within that time frame. Moreover, the learner, material, and teacher all shift in response to one another. Unlike standardised tests and research, DA is not the constant application of a method over time but is the immediate shifting of adjustments in reaction to the learner's response. Needless to say, the longer the time period, the more data there are to support even deeper analyses of emerging research patterns. From a research perspective, it would be best to introduce modelling tasks to learners with SEN over several years. Unfortunately, this was not possible in this study because of time constraints compounded by international gatekeeping practices pertaining to ethical clearance and visa requirements.

1.6.3.2 Dynamic assessment and the scope of the intervention

It is standard practice in DBR to design an artefact or learning product through cycles of planning, implementation, evaluation, and subsequent revision. In general, the focus is on improving the artefact itself. This study comes from a slightly different focus. To explain, I use DBR, not as in standard practice to improve an actual learning product, but as a way of improving how one works within an approach to support the engagement in modelling of learners with SEN. As discussed earlier, support in this context is to design tasks to draw out weak cognitive functions and to strengthen them, which in turn will strengthen the modelling building and mathematical learning of learners with SEN. Put differently, contrary to standard DBR research, in this study the task or the design artefact is not the end in itself, it is the means to the end. Therefore, the focus is on how to adapt the modelling approach for learning to occur. The unit of analysis is the approach itself and how it can be supported to accommodate learning, and not the learning products that were designed for the study.

1.6.4 Contraventions between the nature of modelling and the type of intervention proposed by Feuerstein

There is an inherent tension between Feuerstein's notion of strengthening vulnerable cognitive functions and modelling in that Feuerstein's approach is akin to immediate, direct, and structured intervention to address the situation, while modelling's inclination is to rely more on learner directives and action initiatives. Initially, the type of integration I propose will skew the nature of modelling away from its learner-centred administration and execution to be more teacher-directed in nature. However, a key point to take into account is that the purpose of the teacher intervention is to strengthen cognitive functions, and for these emergent psychological functions to become independent through frequent intervention. With this in mind, it is expected that learners will grow cognitively and become more independent in their abstract reasoning, thereby allowing the teacher to withdraw and the modelling system to restore its balance in terms of learner-directed activity.

Moreover, some readers may disapprove of Feuerstein's use of deficit language. It is important to remember that Feuerstein's writing was a product of his time. He wrote before strengths-based and solution-based philosophies became popular. In spite of the language he uses, a key point is that his message is one of hope and optimism and not of blame and shame. He argues that these deficits can be strengthened to the point where learners with SEN can become real learners and not just receivers of support. Consequently, authors using his constructs typically rephrase his statements by writing them in the positive (Tzuriel, 2000). To illustrate, the term *cognitive deficits* can be replaced with *cognitive functions* and each cognitive deficit can be written in a positive manner. For example, the cognitive deficit of *blurred and sweeping perception*, can be restated as *focus and perceive.* In this study, I use both terms interchangeably, but overall I prefer cognitive functions as a way of bypassing stereotypes and pre-judgements connected to deficit models.

1.7 ORGANISATION OF THE CHAPTERS

Chapter 1 provides an introduction and a background to the study.

In Chapter 2, I review the literature on inclusive practice for learners with SEN by providing a critical reading of the major movements in disability theory and in learning theory. In the review I analyse the influences of these movements on inclusive practices, in particular on helping learners with SEN access common core curricula. The chapter concludes with a reading of Feuerstein's theory and how it compares to current inclusive practices.

Chapter 3 continues the literature review and presents critical elements of mathematical modelling by relating it to theory and by discussing the roles of learners and teachers in a modelling setting. Thereafter, some consideration is given to the potential benefits and limitations of modelling tasks for learners with SEN. At the end Feuerstein's theory is reintroduced as a bridge between modelling and the needs of learners with SEN.

Chapter 4 describes the process of developing the modelling program and designing its implementation in the classroom, including the pre-evaluation of the programme. In addition, Chapter 4 contains a discussion and review of the research methodology used in the study, with justification for its choice. The research methodologies in the study are described in detail, together with ethical considerations and a summary of the methods used to ensure the reliability and validity of the research.

Chapter 5 presents the analysis of data and discussion of each of the research questions. For this purpose, Chapter 5 describes the cycles of the design, its implementation, and reflection on its implementation and subsequent modification.
In Chapter 6, three cases are discussed in relation to the characteristics, the processes, and the representations of the learners. The last section relates data back to the primary and secondary research questions.

Chapter7 presents a summary of the research, together with the limitations of the study and recommendations for further research.

CHAPTER 2
AN ANALYSIS OF THE CRITICAL CHARACTERISTICS OF LEARNING ENVIRONMENTS FOR LEARNERS WITH SEN TO ACCESS COMMON CORE CURRICULA

2.1 INTRODUCTION

This study takes place in a special needs environment. For this reason it is worthwhile to connect with some of the key constructs around best-practice from a disability perspective. Then again, special needs education is a contested terrain. Its rationale and its existence as a parallel system to mainstream education are being questioned. Likewise, the nature of special needs education is caught up in perpetual debates as to the who, the what, the where, and the how of special needs learners. Who should be defined as special needs learners? Where should they be taught? How should they be taught and what should they be taught? Needless to say, these debates are far from settled. In reality, there is no panacea or Holy Grail, more a melting pot of ideologies. Nonetheless, these perspectives share the presence of strong voices that serve to inform and guide instructional designs. This chapter serves the purpose of fulfilling Task A of the study, given that Task A is as follows:

> **Task A: Define the critical characteristics of learning environments for learners with SEN to access common core curricula**

In this chapter, I discuss the following:

- the current tension of inclusive practice in relation to curricular matters;
- how disability models influenced policy and led to education-for-all in policy;
- what has been done so far to make inclusion a reality in practice;
- how effective these efforts have been;
- and, what still needs to be done.

For the most part, evidence suggests that learners with SEN have inclusion in terms of place but not in terms of their learning. To this end:

- I revisit major learning theories and discuss how they inform learning in SEN environments.
- I propose Feuerstein's Structural Cognitive Modification theory as a bridge for learners with SEN towards accessing common core curricula.

2.2 "ACCESS TO COMMON CURRICULA" TENSION

The tension I want to pay attention to in this study is the *Access to Curriculum Dilemma*. In short, it has to do with giving learners with SEN full access to the mainstream curriculum. Full access is taken as *all aspects* of the curriculum. Taken from a broad perspective, it is about extending the quality of what is generally available to an increasing range of learners. Further on in this study, it has the specific application of how to engage learners with SEN in mathematical modelling tasks while facilitating worthwhile learning at the same time.

2.2.1 Historical progression

Historically, this ideal of inclusion in respect to curricula has been taking shape over the last four decades. Browder, Spooner and Meier (2011, p. 9) discuss the historical progression of the debate on what curricula foci would be most suitable for learners with SEN. In the 1970s, education was given a developmental focus where learners with disabilities were instructed according to their mental age. Ideas such as Binet's (1916) seminal idea of mental age and Séguin's (1866) notion of infantilism were applied directly and consequently materials were taken from early childhood curricula. However, it was realised that this kind of work was neither age appropriate nor did it equip learners for life. To overcome these limitations, curricula developers shifted focus back to the chronological age of the learners and on developing skills that are age appropriate, rather than adjusting tasks to mental-age specifications. With this in mind, a functional focus developed with an emphasis on skills that learners would need in their communities. Again, limitations emerged, and the one that received the most emphasis was that learners with disabilities were physically removed from their non-disabled peers. In the 1990s, inclusive practices became prominent. During this period, there was an additional emphasis on self-determination and the need to train learners with disabilities to make choices and to set their own goals. Since 2010, the emphasis is on supporting these learners to access general curricular content. In international policy, it is now established that learners with SEN should have access to mainstream curricula, which is also the case in Australia.

2.2.2 Supported in the national curriculum

The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2013c) acknowledges the commitment in the *Melbourne Declaration on Educational Goals for Young Australians* (2008) to ensure support for all learners with the goal of them becoming active and empowered citizens of Australia. Moreover, educators are obliged to use the Australian Curriculum in a way that complies with the requirements of the Australian *Disability Standards for Education (Commonwealth of Australia, 2005) under the Disability Discrimination Act 1992*, ensuring that all learners with disability are able to participate in the Australian Curriculum on the same basis as their peers (ACARA, 2013a). The term 'on the same basis' is defined on their website as follows:

- 'On the same basis' means that learners with disability should have access to the same opportunities and choices in their education that are available to learners without disability.
- 'On the same basis' means that learners with disability are entitled to rigorous, relevant and engaging learning opportunities drawn from the Australian Curriculum and set in age-equivalent learning contexts.
- 'On the same basis' does not mean that every learner has the same experience, but that they are entitled to equitable opportunities and choices to access age-equivalent content from all learning areas of the Australian Curriculum.
- 'On the same basis' means that while all learners will access age-equivalent content, the way in which they access it and the focus of their learning may vary according to their individual learning needs, strengths, goals, and interests.

Importantly, through these two legal documents the Australian Curriculum initiative recognises the potential of learners with SEN to contribute to society as well as the need to grant them access to life opportunities through the appropriate differentiation of educational tasks and educational environments. These documents are in line with international commitments such as the significant *Salamanca Statement and Framework for Action on Special Needs Education* (UNESCO, 1994).

Disability advocates want learners with SEN to have access to a common core curriculum, and their efforts have achieved *education for all*. In reality, access is so strongly advocated in some areas of the USA and Europe that the concept has moved into a state of entitlement where families of learners with disabilities advocate that their children are entitled to this type of access (Ware, 2014, p. 492).

Even so, the situation begs the question of "now what?" Securing learners access to a curriculum does not mean that they will succeed at it nor benefit from it. All things considered, how appropriate is a common core curriculum to people with disabilities? How relevant is a general curriculum to their needs? To what extent would they be able to access it and how should we best support them in this? How do we make this reality an ideal for learners with SEN without setting them up for academic failure?

2.2.3 The developmental delay model

As SEN educators we have the situation where there is strong support for learners with disabilities having access to common curricula. The next step is to make this right a reality in the classroom. Views on how to achieve access converge into the developmental delay dilemma (Hodapp, Griffin, Burke & Fisher, 2011, p. 194). Those who hold to a developmental view believe that there is a common sequence to human development and that learners with SEN will get there, just more slowly. In other words, they need more time than typical learners since they have not reached certain stages of development or have reached it too slowly. Consequently, developmental reasoning tends to lock this cohort into associations with early childhood development and infantilism (Carlson, 2010, p. 409 Kindle edition). Theorists from the delayed perspective cohort, however, maintain that learners with SEN are fundamentally different, and that they need intervention. This latter perspective is the one from which I write this study. I argue from the writings of Feuerstein and his colleagues (Feuerstein *et al.*, 2010) that learners with SEN are different to typical learners in terms of their brain structure and function. Specifically, the difference I am referring to is that in comparison to their peers, learners with SEN have certain cognitive deficits which need to be strengthened before they will benefit from the type of domain knowledge implicit in a common core curriculum.

All things considered, the developmental-delayed dilemma does not stand in isolation. It is fully intertwined and entrenched in larger debates with deep historical roots. For now, I want to shift attention to tracing the origins and histories of these dilemmas and to show their connection with other debates in the field. Although the ideologies become quite convoluted, awareness of them creates an understanding of the intentions behind decisions about curricula and an appreciation of the bio-political-social influences.

2.2.4 Models of disability which influence curricular decisions

Historically, four major paradigm shifts happened that changed the way we see and interact with people with disabilities. These are the shifts from organic to non-organic, qualitative to quantitative, static to dynamic, and visible to invisible portraits (Carlson, 2010, p. 23). It must be remembered that there were times in history when people with intellectual impairment were seen as non-human or even animal-like in nature. This change in perception to accepting that disabled individuals were human beings is referred to by Carlson (2010) as the shift from the qualitative to quantitative view. Acknowledging that disabled people were indeed human was made possible by the work of change-agents such as Édouard Séguin (1812-1880), who was a physician and educator and an establisher of schools for the mentally retarded in Paris and America. Séguin (1866) is amongst those who advocated the developmental perspective, stating that people with intellectual impairment are quantitatively different and not qualitatively, meaning that they differ in the intensity and the degree of their development and not in their natures as human beings.

Thereafter, theorists wanted to measure the difference between typical people and people with disabilities. To this end, they invested in tests and measurement systems as systematic and objective means of making the invisible visible. For example, IQ tests emerged to make the invisible side of intellectual impairment visible by assigning to it a numerical score. Carlson (2010) refers to this as the shift from the invisible to the visible.

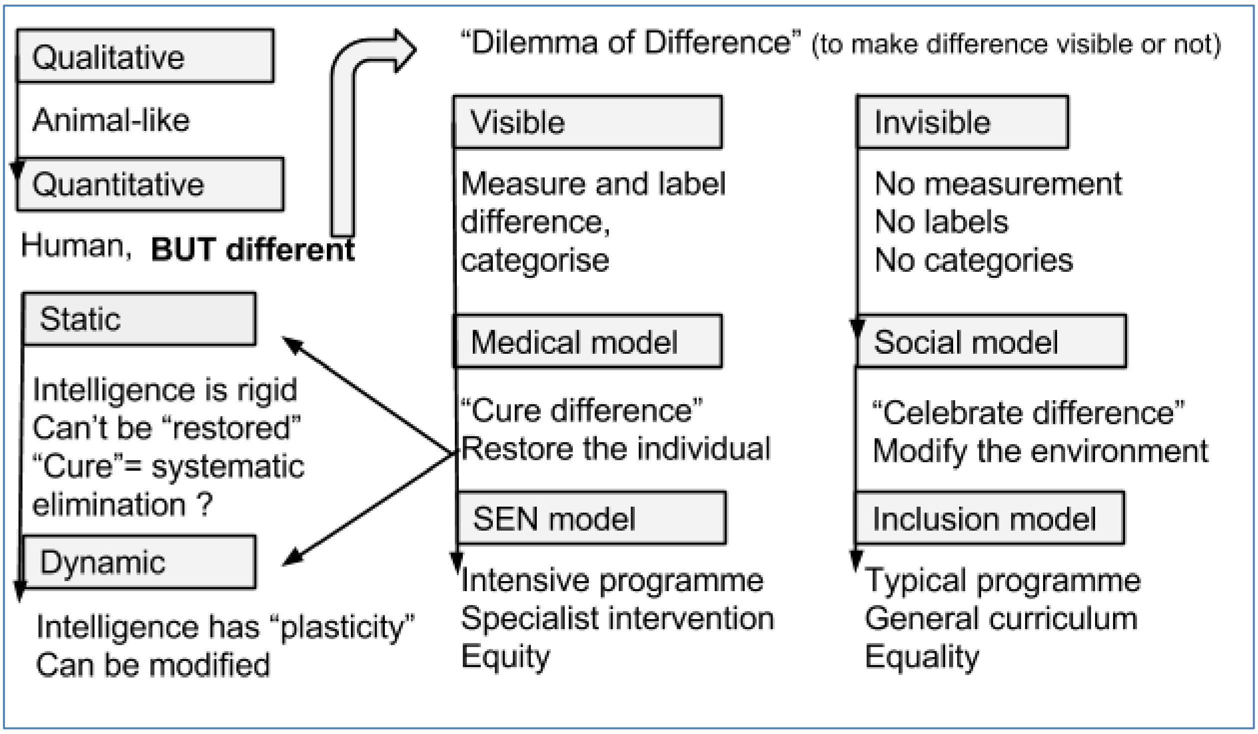
Aside from being aware that people with disabilities are different in certain ways compared to people without disabilities, specialists naturally wondered what to do about the situation. One school of thought gave attention to the differences between ability/disability and the possibility of "curing" the individual. The other school focused on the commonalities between ability/disability and their shared human experiences. Whereas the first group wanted to restore and rehabilitate the individual, the second group was concerned with how the environment (and not the disabled person) should be changed to accommodate all people's growth and development. Ralston and Ho (2010, p. 16-19) discuss the historical progression of the two dominant models used to define disabilities, namely the medical model and the social model of disability.

Around the 1960s, the discourse on disabilities was largely from a medical perspective with a focus on biological or mental abnormalities and their rehabilitation or cure. One dimension of the ultimate cure was the strong support of negative eugenics, which peaked in this era and that supported the idea that "weakness" had to breed out. A photographic exposé of the challenges of these times can be found in Burton Blatt's book *Christmas in Purgatory* (1966).

The 1970s saw the emergence of the social model of disability, which involved the development of systematic studies of and social policies for people with disabilities, revising linguistics around how people with disabilities should be referred to and the deinstutionalisation of people with disabilities (Ralston & Ho, 2010, p. 16-17). The move away from the medical model to the social model marked a shift that can be described in many different ways — from charity to civil rights, from an individual focus to a societal emphasis, from looking inside the individual to looking at factors outside the individual, from medical to political, and from organic to non-organic. Concepts around the notion of adjustment became re-orientated. The idea that it was no longer the individual who had to adjust, but that society had to adjust to the individual in a physical, social, and environmental way, became established as one of the primary principles of the social model (Engelhardt, 2010, p. 238).

A question that emerged from the need to rehabilitate individual with disabilities is whether intelligence can be modified. In other words, once intellectual impairment has been "measured", can it then show change in a positive direction? There were significant periods in history where intelligence was seen as determined by heredity and consequently treated as an invariant and static determinant of functioning over life span (Martinez, 2000). Feuerstein was one of the first psychologists to challenge this assumption through his work of structural cognitive modifiability. Moving from seeing intelligence as fixed to regarding intelligence as modifiable is known as the shift from the static to the dynamic.

Figure 2. 1 Carlson's four major paradigm shifts and the Dilemma of Difference



For the most part, SEN customs align more with the medical model and use practices like testing the individual, individual intervention, and separate specialist services. By contrast, inclusion advocates a mainstream environment for all learners and maintains that this can be achieved through adjusting the environment by broadening it to cater for a bigger range of needs. Efforts to broaden the environment include changing the beliefs and the practices of the teachers in the interests of better accommodating diversity. Carlson's four shifts, how they relate to the social and medical model, and to SEN and integrated practice are depicted in Figure 2.1.

It is becoming increasingly apparent that both the social and the medical model are still very much consumed with limitations and are at risk of consigning people with chronic disabilities to unsatisfactory lives of tragedy and misery (Ralston & Ho, 2010, p. 18). For example, the medical model assumes that if a person who has a disability cannot be rehabilitated or 'cured', the quality of that person's life is also permanently impaired. A direct correlation between quality of life and health is proposed (Ralston & Ho, 2010, p. 17-18). By the same token, the social model alludes that the unavoidable consequences of having a disability are social exclusion and a life of poverty and isolation.

Consequently, the philosophical stage is ripening for theories that hold more positive outcomes towards the disabled, such as the acknowledgement and advocacy that a person with a disability may very well have the capacity for a full and happy life (Johnson, Walmsley & Wolfe, 2010). Some of the more right-wing approaches are redefining disability in relation to normalcy by replacing impairment with normalcy as the baseline measure (Quigley & Harris, 2010, p. 136). Put differently, these paradigms shift perspectives to give more credence to normalcy and to recognise society's obligation to enhance even healthy lives. Failure to do so is considered disabling. The reasoning in this ideology is that people who fall within the range of what society deems normal can now be viewed as disabled when they become shut out from important societal opportunities and experiences.

I place myself alongside the philosophers and practitioners who are becoming increasingly dissatisfied with the deep trenches that have been dug between the social model side and the medical model supporters. I agree with those who seek positive input from both models to enrich the life quality of the disabled person (Silvers, 2010, pp 34-37) and who argue that at least neutral ground, and at best, common ground has to be found and developed to move special education forward. Above all, I assert that it is naive of educators to degrade or dismiss the expertise of the medical model practitioners such as speech therapists, occupational therapists, physiotherapists, paediatricians, and so on. At the same time, educators need to continually adjust the social and physical environment of the classroom, and the school itself, to facilitate and gradually optimise sound academic learning and social inclusion practices.

Attempts to reconcile the two dominant competing models are the biopsychosocial approaches (see Emerson & Hatton, 2013, p. 2-3 for specific examples). Biopsychosocial approaches consider how to best accommodate the interplay between physical/biological impairments, activity limitations, and social participation restrictions and the environment (for example living conditions, policies, rights). It must be remembered that all these factors come into play in a SEN classroom.

Equally important are the principles from quality-of-life models that direct pedagogical interventions and foster independence through personal development and self-determination. In the same fashion, these models encourage social participation through relationships, inclusion, and the promotion of rights of disabled learners, while all the time taking care to protect the physical, emotional, and general well-being of the learners (Schalock, Keith, Verdugo & Gomez, 2010, p. 21-22). Yet, I maintain these kinds of adaptations need to be physiologically informed and made in sensitive co-operation with medical diagnoses and not through their dismissal.

The model that best informs this study is the transactional development model introduced by Sameroff and Chandler (1975). In this model, attention is given to the interplay between environmental influences and the learners' aptitude, which helps them, through social support, reach central developmental tasks during the course of schooling. This model acknowledges a mutual and dynamic influence between the learners and their environmental factors, where both can be changed as a consequence of the interaction (van Sweta, Wichers-Botsa & Brown, 2011, p. 910). An extension of the transactional development model is the current solution-focused approach, where the learners become agents with empathetic and supportive adults in the decision making processes about their learning, behaviour, and well-being (van Sweta *et al.*, 2011, p. 910).

2.2.5 The implications of disability models for learners with SEN

To summarise, what does the evolution and progression of these models mean for SNE? In reality, although these models may seem esoteric and removed from the practicalities of running a classroom, their influence cannot be underestimated. These debates are powerful in that they define disability. For example, their influence has moved the terminology of intellectual impairment along from earlier terms such as idiot, moron, and mentally retarded to the current definitions of intellectually impaired, developmentally delayed, and intellectually disabled (Harris, 2005, p. 3; see Goodey, 2011, p. 4 for a fuller list of historical terms). Terminology aside, the models operate on a much deeper level by opening up the proverbial and ethically loaded Pandora's Box around topics such as medical intervention, life creation and extension, social justice, and eligibility of financial support for certain types of services. These factors in turn affect the nature and quality of care that is funded and assimilated into educational interventions. In short, through these models we define who learners with SEN are and what they should and should not have available for them when at school in terms of classroom allocations, support staff, and resources. It is important to realise that their influence reaffirms that the curriculum never stands alone. In reality, the political level and the pedagogical level share common space, making curricula the product of existing social discourses, and demonstrating that education is as much moral and political in nature as it is practical and technical.

Accordingly, I concur with Norwich's observation (2013, p. 256-264) that tensions in SEN settings are fuelled by the current values of Western plural and liberal economies, the introduction of market principles into the school setting, and the ongoing philosophical questions related to the ontological nature of disability and the function of epistemology around disabilities. At the same time, it would be naive to assume that motives of the different models are necessarily pure and filled with good intentions towards the disabled. For example, whereas the ideal of helping disabled people access the employment market seems noble in itself, a mere glance at the debates between the neoliberal and neoconservative camps reveal very different motives underlying this end.

Norwich (2013, p. 256-265) makes another significant observation. He observes that most of the positions in special needs education have been set up as dichotomies — inclusion or SEN, mainstream or separate, the medical model or the social model, direct instruction or constructivist approaches, and traditional teaching or modelling. The natures of these dichotomies are such that they translate into oppositional vibes that do not lend themselves to reconciliatory or combinatory intentions. To a large extent therefore, special needs practice has habituated separatists and segregating mindsets, and it's only very recently that theorists are beginning to imagine what common ground could look like, and this may prove to be transformational.

2.3 HOW DO WE GET LEARNERS WITH SEN TO ACCESS COMMON CURRICULA?

As was noted above, getting learners with SEN to work with common core curricula has a historical background. UNESCO (2005, p. 9) states how learners with SEN were moved into mainstream through an approach known as integration, and the main challenges around learners with SEN and mainstreaming are that integration has not been accompanied by changes in the organisation of the ordinary school, its curriculum and teaching, and learning strategies. In the next section, I critically analyse each of these categories — integration or socio-spatial inclusion, restructuring staff and systems at school level, differentiating the curriculum, and using multimodal teaching and learning strategies such as Universal Design for Learning. In addition, I also include the use of para-educators as a strategy for helping learners with SEN access mainstream curricula.

2.3.1 Socio-spatial inclusion

For a while, the placing of learners into special needs units instead of into mainstream was seen as the real nemesis preventing learners with disabilities from accessing common curricular materials. Those in favour of full inclusion argued that special needs units both facilitate and hinder learning; that they lead to lifelong stigmatisation, are associated with low expectations, reduced curricula, limited opportunities for typical peer interaction, lead to high costs per learner, represent a disproportionate number of migrant and ethnic minorities, low socio-economic groupings, and boys; and, that there is not enough evidence to support the belief that they produce better learning outcomes than mainstream environments (Powell, 2014, p. 340-343). It was reasoned that by changing the socio-spatial inclusion of learners with disabilities that these issues would change for the better as well. To this end, the ideal became placing learners with SEN in mainstream with their peers and treating them exactly the same as all the other learners with respect to their learning and persons. Although the intention to normalise difference as a way to protect learners from segregation and stigmatisation should be pursued, we must also remember that, in reality, negative aspects of social stigmatisation and de-evaluation can happen in the absence of SEN environments and often predate entry into a SEN environment. In other words, negative societal response may not so much be in response to the SEN label itself but to what SEN represents, which is being "different". There is a question underpinning all these challenges, which runs across broader societal platforms and has as yet not been satisfactorily addressed, namely, "How do we respond ethically to difference?".

In reality, socio-spatial inclusion did not address all the issues relating to learners with SEN as successfully as hoped. Instead, it created a series of paradoxical research encounters.

For instance, the increase in inclusion has not been empirically matched with a decrease in segregation. For the most part, research reveals concurrent growth in both special needs education and inclusive education in certain situations where inclusion has been introduced (Powell, 2014, p. 344-346).

Besides, it emerged that normalising difference comes at a price for learners with SEN. A core unresolved issue within the inclusion debate is referred to by theorists as the *Dilemma of Difference* (Minow, 1990, p. 12). In this dilemma, it is recognised that placing a special needs learner in a mainstream environment without additional support or placing a learner in a special needs classroom for support purposes will both have ramifications that could lead to forms of separation, devaluation, and stigmatisation. In other words, the differential stance, which is to provide the learner with SEN additional resources and intensive teaching support, and the commonality stance, which is to only use ordinary resources and support general to all classrooms while maintaining a kind of invisibility around the disability, may impact negatively on the learner (Norwich, 2013, p. 1185).

Research confirms that certain learners require individualised learning programmes to cater substantially and comprehensively for their individual strengths and vulnerabilities (Lauchlan & Boyle, 2007, p. 35). .For example, Kershaw and Sonuga-Barke (1998) observed that learners with emotional behavioural disorders have higher disengagement from school in spite of them having the same curricula and behaviourist interventions as the general populations. They argue that to keep these learners in school, schools have to engage in much *greater levels of differentiati*on to meet individual differences. The study shows how learners were included in mainstream settings yet failed to engage in their learning, which led to them leaving school altogether. Needless to say, disengagement from school has significant societal ramifications and is one of the least desired results in education. By the same token Forbes (2007) and Konza (2008, p. 39-60) discuss the perceived benefits and challenges to teachers, learners, parents, and administrators with regard to accommodating learners with SEN in mainstream settings in the Australian context. Since educators typically want their learners to experience success under their teaching, it becomes important to gain insights into when learners are most likely to adapt well to mainstream environments. With this in mind, Cook, Tankersley, Cook and Landrum (2000, p. 117) use the *theory of instructional tolerance* as a guideline for anticipating which of the more vulnerable learners will most likely succeed in mainstream environments and which ones will probably face exclusion amidst inclusion. The theory of instructional tolerance posits that learners who reward teacher investment of time and effort and who display some success will typically attract more teacher concern and attachment. In other words, it is easier for learners with SEN who have a speech impediment or a physical disability to evoke concern from teachers, even if they do not achieve many learning gains, than it is for learners with SEN who have behaviour challenges and who demand and receive a great deal of teacher time, typically not instruction-related. The latter situation affects teacher perceptions of their own personal competence and consequently their satisfaction of working with such learners.

On the whole, I view the inclusion of learners with SEN into mainstream classes as a very positive move and celebrate the successes that have been achieved through the tenacity of the movement. It is important to realise that inclusion is a necessary and a significant step forward in the lives of many learners with disabilities and their families. Regardless, it is sobering to acknowledge that inclusion is not yet working for everyone. All things considered, the current and growing existence of SEN units in full inclusion settings are indicative of the failure of mainstream systems (Florian, 2014, p. 9).

Essentially, I argue that inclusionists and separatists are guilty of the same thing. They have both purposed to fit a learner with SEN, any learners with SEN for that matter, into a model which they have predetermined and preconceived as the ideal according to their philosophies, irrespective of the learner. In contrast, my position is that paying attention to the learners, genuine attention, necessitates a transparent, honest, and joint exploring of dynamics between these models in a localised setting. Again, the dichotomy between SEN and mainstream is not in the best interest of the learners and needs to be bridged. Ultimately, SEN and inclusive practitioners want similar outcomes — to minimise barriers and to maximise participation and meaningful learning. Interconnectedness between SEN units and mainstream would ensure better educational outcomes in diversity. It is also important to extend the interconnectedness between SEN and mainstream domains to include the variety of institutions which learners with SEN typically access, for example, the labour market, the juvenile justice system, the health system, and welfare. In the final analysis, I support the notion of "responsible inclusion", instead of "full inclusion" (Evans & Lunt, 2002).

All things considered, there is enormous impetus to helping learners with SEN access core curricula. I focus on five efforts that have been put in place worldwide to help in this regard. These support structures are improving teachers' knowledge and teaching quality, differentiating curricula material, diffusing Universal Design for Learning

(UDL) as an option for instructional design, appointing para-educators, and assisting in acquiring assistive technologies.

2.3.2 Staff and structural re-organisation

With the presence of learners with SEN in mainstream classes, teachers are feeling the tension of managing the increasing levels of heterogeneity. As the structures of classes are changing and becoming more diverse, the restructuring of staff is being considered. It is important to realise that inclusive practice is also a debate on replacing specialist teachers with specialised teaching (Norwich, 2013, p. 1860 Kindle edition), given that if general teachers became better all-rounders, then special needs educators would not be required any longer. To this end, specialised teaching includes educating generalist teachers to deal more effectively with learning difficulties and disabilities by increasing their knowledge in pre-service training, by changing their pedagogical practices to be more diverse, and by teaching them how to differentiate the curricula. The ideal is that that *all learners* in the class will have access to specialised practices by integrating and merging these differentiated operations into general practice to the measure that the specific becomes the general. If successful, it would eliminate the need for separate special needs services, thereby deinstitutionalising them. By the same token, it would eliminate the need for individualised learning tracts. The thinking is that when all learners share a common core curriculum and every learner receives specialised teaching as the norm, then all learners will access the curriculum successfully. Again, there are many difficulties in terms of application. Forlin (2012, p. 7-8) concludes that global challenges in this regard include a breakdown between policy makers and teacher training facilities, a breakdown between teacher training facilities and suitable practicum placements, and the high cost of upskilling teachers, amongst others. Under these circumstances, teachers are feeling inadequately prepared for dealing with diversity.

Yet others foresee special needs educators continuing in their role of helping learners with SEN access the curricula. For example, Florian (2014, p. 9-14) argues that the debate is not so much about the presence of special needs expertise but more about the positioning of special needs services. In other words, schools need access to special needs resources, but the question is whether to have these services as an integral part of mainstream operations or to have them as a marginal service to mainstream activities. Florian describes the traditional position as the *boundary of the bell-curve*, referring to the fact that special needs educators typically deal with learners who are at the tail end of normal distribution, and comparatively, special needs services continue to exist on the outskirts of mainstream setups. She argues that it is time to move special needs services, metaphorically and in physical reality, closer into the centre of the normative, with the normative referring to mainstream.

Regardless of the position of special needs educators, the main idea is that learners with SEN participate in the same curricula and in the same tasks as their age-typical peers, but that they do so at different levels and in different modes.

2.3.3 Differentiation

In Australia, the Disability Discrimination Act (1992) and the Disability Standards for Education (2005) support the enrolment and full participation of learners with disabilities in mainstream schools. Accordingly, principals and schools can meet their obligations under the Standards by giving consideration to *reasonable adjustments* to ensure that learners with disability are provided with opportunities to participate in education and training on the same basis as learners without disability. Before any adjustments are made, *consultation* takes place between the school, learner, and parents or carers (ACARA website, 2013a).

Differentiation is largely about adapting curriculum materials, learning outcomes, and assessment strategies to cater for diverse learning needs. Historically, special needs educators were expected to be specialists in pedagogical adaptations. As was noted earlier, more recently there has been increasing pressure on all teachers to differentiate their materials through adaptations. Norwich (2013, p. 1670 Kindle) identifies common areas of adaptations and their functions. He states that educators need to adapt programme goals, teaching presentations, and learners' response modes to teaching. Adaptations also include adjusting learning objectives and the mode of teaching. Lastly, educators have to be sensitive to the social-emotional climate of the classroom and to establish positive relationships with the learners. The first type is deemed a necessary adaptation for sensory-motor challenges, the second is typical for learners with cognitive impairments, and the last type of suggestion is more applicable to learners with emotional-behavioural issues. Adaptations fulfil certain important functions like helping learners accept their difficulties, finding socially appropriate ways of circumventing barriers, remediating and reducing certain barriers, and restoring function.

Besides differentiation, there is another considerable issue to aligning the work of learners with SEN with a national curriculum such as ACARA. This matter concerns adequate assessing and reporting against the national standards. Whereas educators may be able to soften learners' vulnerabilities from others in the classroom through differentiation, it is harder to circumvent the fact that they perform well below their peers. Moreover, their low attainments are made public through an ongoing cycle of assessing and reporting. Swann et al. (2012, p. 3) aptly named it the *ladder* method since there is a public ranking of the performance and attainment levels of learners in comparison to their peers. Measuring through testing, standards, and achievement criteria is meant to show that learning outcomes can be controlled and that schools can be made accountable in this way. This is important to politicians in their efforts to raise educational standards against national settings, and it is also strategic to market the school to prospective parents by referring to pupils' performance levels. However, in trying to measure outcomes, knowledge is typically reduced to a set of measurable performance or success criteria, thereby excluding a range of meaningful knowledge ends which do not lend themselves to this kind of measurement. Under these circumstances, Swann *et al.* (2012, p. 4) argue that authentic learning is being substituted by attainment. Should national testing not be handled carefully, there is risk of creating a system based on meritocracy where learners with SEN lose out and lose face at the same time, where learning is measured by performance indicators that are too narrow, even inappropriate, and where real learning is undervalued and even damaged.

Under these circumstances, authors such as Hart and Drummond (2014, p. 439) argue against traditional forms of differentiation for learners with disabilities. They realise that from a traditional perspective, differentiation is simply another form of an ability focused tracking system where the less able are reduced to more simple tasks, the able to average tasks, and the most able to extension tasks. Granted that, it continues the trend of characterising people according to their limitations.

From a subject perspective, Ben-Hur (2006) argues that differentiation in mathematics, which is, giving perceived high-ability, challenging maths tasks and giving lower-ability, easier maths tasks is not necessarily helpful either. He argues that this type of differential consequently creates a flawed logic that there are different "mathematics" (p. vi and vii).

On the other hand, there are more radical forms of differentiation that appear to be working. For example, Hart and Drummond (2014, p. 447) explain how one school has achieved success by shifting from differentiation to co-agency. To explain, instead of differentiating, teachers design a series of tasks at various levels of challenge. Thereafter, they use the principle of co-agency, meaning that learners share responsibility with teachers in their learning choices. Accordingly, learners themselves select the level of task they want to attempt, learners choose the level of support they want, and learners indicate if they want support from peers through collaboration or from the teacher assistants. Additionally, the Universal Design for Learning (UDL) movement is a more recent methodology for differentiation that is gaining in popularity in inclusive circles.

2.3.3.1 Universal design for learning

The UDL method is essentially about adapting teaching presentations and learners' response modes by allowing for multiple learning pathways and/or multiple solutions. The reasoning behind the model is to be flexible and extensively varied in the design of instructional tasks, both in terms of what teachers do and what learners do, so that diverse learners can access the material and demonstrate their knowledge and skills in assessments. The UDL website (CAST, 2011) contains a set of guidelines and examples for teachers on how to implement UDL effectively.

Hall, Meyer and Rose (2012, p. 2) explain that the main principle of UDL is that learning tasks have to map onto or activate three brain states, namely the recognition network, the strategic network, and the affective network.

- Recognition learning is supported when the pedagogical situation allows for *multiple pathways of representing* the information as a teacher and as a learner. Simply put, teaching-learning situations must be multi-modal or multi-sensory in nature.
- Strategic learning is supported when the learners can use m*ultiple forms of actions and expression to convey what they have learnt*. A main principle of strategic learning is to stimulate as many executive control mechanisms as possible. Digital technology plays a large role in all areas of this model, but particularly in the area of helping learners produce their learning outcomes in different modes, for example, by presenting their work as video clips, music, digital photography and/or animation.
- Affective networks are activated when learners are given *multiple modes of engagement* to generate and sustain their interest. Motivation is also an important aspect of controlling their impulses and helping them regulate. When learners are deeply involved in tasks, they are more likely to stay focused and less likely to act out.

2.3.4 Learner support assistants

Learner Support Assistants (LSAs) are also referred to in literature as teacher aides and para-educators. Giangreco, Doyle and Suter (2014, p. 695) did an extensive study on the role of LSAs across several countries, including Australia. They identified that the use of LSAs is increasing. At the same time, LSAs are expected to perform a wide range of tasks in relation to the learner, including behaviour management, personal care such as toileting, and instruction. Often these tasks and roles are beyond the LSAs' levels of training. Moreover, their employment conditions are far from ideal (part-time contracts, lower pay, and challenging learners), which diminish their sense of work satisfaction.

There is a more pressing question in terms of relevance to this study. How much do learners with SEN benefit in terms of their learning when it comes to having the support of a LSA? Webster *et al.* (2010) report recent findings from a very large study of LSAs (the Deployment and Impact of Support Staff (DISS) project) in England and state "TAs [LSAs] in the UK have become the primary educators of pupils with SEN, and that there is a strong negative effect of TA [LSA] support on the academic progress of these pupils" (p. 329). On the whole, LSAs were more focused on task completion than on actual learning.

Aside from concerns over learning, other issues such as learner voice and self-determination are emerging. In some instances (Swann, Peacock, Hart & Drummond, 2012, p. 3)., where the least abled are given separate tasks to the rest and are appointed a teacher assistant to complete tasks with (and at times teacher assistants do task for learners), it was observed that members of the lower ability groups would lose faith in their own competence and would not work unless an adult was working with them. In addition, it was noted that those in the highest ability groups became competitive and unwilling to ask for help

2.4 THE NEED FOR MORE RESEARCH

At present, some penetrating questions are being asked around education efficacy that inclusion and SEN domains will have to answer in the near future with a deeper analysis than is currently present in their literature. This comes in the wake of recent research such as Rix and Sheehy's (2014, p. 459) review, which indicates that neither having learners with SEN in SEN environments nor having learners with SEN in inclusion settings have delivered significant educational gains. Based on the results from this survey, when comparing progress of learners with SEN in inclusive settings to progress of learners with SEN in separate settings, the former shows only marginal gains.

Thus far, promoters of inclusion share the assumptions of the social model of disability. The social model values societal acceptance and envisages the learner having access to friends, being part of common cultural experiences and conversations, and having a feeling of belonging and a shared common identity. With this in mind, advocates of the social model have challenged and changed societal perceptions and values, segregation policies, and gate keeping practices to get children with disability accepted and placed in mainstream schools. To their credit, they have reached a certain level of success, more so in developed countries than in third-world ones. Simply put, the insistence on inclusion has given parents the right to choose alternatives to SEN settings.

More recently, a relatively new type of tension is surfacing, which is related to choice and equity or making choices in respect to equity (De Valenzuela, 2014, p. 310; Black-Hawkins, 2014, p. 394). Under present circumstances, the right to education is now being replaced by rights in education. To explain, the challenge is no longer in securing a physical place in a specific school setting and in getting a foot into mainstream, nor is it about the disabled learner being treated the same as the abled one. The onus on educational units, whether mainstream, specialist, or alternative, is to demonstrate with evidence that learning is taking place in that environment. Moreover, to demonstrate that learners in that type of educational environment are benefiting as much, and even more, in terms of their learning than if they were in another educational setting. Put differently, attention is turning away from learnercentredness and social affiliations back to learning-centeredness and educational outcomes. Educational equity is increasingly being associated with learners, individually and collectively, having genuine opportunities to achieve and to learn as members of their classroom community. The historic baseline of success in education appears to be shifting from fairness and equal treatment to relevance and authentic engagement in learning.

2.4.1 What do we already know from research?

Recent research reviews related to the issue of curricular access by learners with SEN indicated that there is still relatively little research evidence on this topic. Additionally, the different approaches adopted by researchers working in different countries make it difficult to compare findings that are there (Ware, 2014, p. 493). However, available research confirms that there is a shift in focus away from equality towards equity in learning. To illustrate, Ware's (2014) study noted that earlier research trends focused on learners with SEN being engaged in the same tasks as their peers in a mainstream setting. In more recent research, however, researchers not only looked at engagement but also at achievement of learners with SEN in terms of the task. This is in line with Black-Hawkins's framework of participation (Section 1.2.1.2) and the need for access to be combined with achievement. Overall, the findings indicated that the stronger the effect of impairment, the more difficult it was for teachers and learners to find ways of meaningfully accessing a general curriculum. To clarify, the data from the review suggested that the stronger the level of intellectual impairment in the learners, the less successful these learners were in engaging in tasks. Correspondingly, the teachers found it more challenging to differentiate for learners with greater levels of intellectual impairment, compared to learners with milder forms (Ware, 2014, p. 494-496). More severe cases were managed by assigning LSAs to those learners with SEN.

Ware is amongst several authors who suggest that more research is needed in this area of education, but at the same time acknowledge some of the difficulties that are keeping research on learners with SEN from making more rapid gains in the field.

2.4.2 Factors hampering research

2.4.2.1 Defining learners with SEN as a research category

Currently, learners with SEN present as a poorly defined super-category in literature (Norwich, 2013, p. 998). The uncertainty around identification is creating unacceptable high levels of variance. Who are learners with SEN really? What set of criteria should be applied to identify them? Where is the boundary between a vulnerable learner and a learner with SEN, or when is a learner vulnerable enough to warrant the support and intervention from a special needs framework? In addition to inferring how having a super category would interfere with effective needs assessments and provision availability and distribution in countries, it is known that this type of broad and vague delineation also creates challenges in research, including research into special needs education in Australia (Ellis, 2005, p. 5; Diezman, Stevenson & Fox, 2012, p. 97; Powell, 2014, p. 339). As was noted in the previous chapter, one of the drawbacks in special needs literature is the labyrinth of definitions being used to categorise learners with SEN. From a research perspective, it means that theorists are left with lots of isolated fragments of knowledge that cannot be consolidated and integrated since it is open to speculation as to whether certain categories of learners are meant to refer to the same research profile or not. Consequently, the varied use of terminology makes it difficult to synthesise research into a more coherent picture. This in turn impedes extending SEN research, for example, by undertaking international and comparative research in relation to categories, opportunities, services, and support (Richardson & Powell, 2011, p. 187).

2.4.2.2 Do we focus on aetiology?

Should research into SEN settings be based on aetiology? To explain, research from the basis of aetiology will consider learners with Down Syndrome and learners with Autistic Spectrum Disorder as two different cohorts, and research them separately based on these categories. To illustrate, this research project would, from an aetiology perspective, only focus on how learners with autism do modelling or how learners with foetal alcohol do modelling, but not put the two groups together.

There are several challenges associated with this view. First, there is the complication that even when learners fall into the same research cohort and share a similar diagnosis, the pattern the disability takes is typically unique to a learner. For example, in conditions such as autism or foetal alcohol syndrome, the way the diagnoses present typically vary significantly from learner to learner, hence the idea of the individual "being on the spectrum".

Second, although still in existence, it is becoming less common to have classrooms dedicated to conditions, which makes studying learning as it occurs in a natural setting in relation to an aetiology more difficult to engineer. On the other hand, South Africa still houses segregated schooling systems for learners with disabilities such as schools for the blind and schools for the Deaf. Third, many learners with SEN have multiple conditions, which would make it complex to discriminate which behaviours are exclusively related to which conditions. Last, if research is to be based on the idea of aetiology, it implies a diagnosis, which means that the learner has to be labelled.

i) Labels and learners with SEN

The labelling of learners with SEN is controversial and relates back to the visible-invisible paradox, given that a label makes the disability visible to society. On the positive side, some authors (Lauchlan and Boyle,2007, p. 36, Boyle, 2013) argue that, aside from access to state money, labels can be useful to provide and promote an understanding of the child's difficulties to the children themselves, their families, and to other professionals working with the child. Having a diagnosis can be a source of comfort and awareness to families, and additionally provide the learner with a sense of social and group identity. On the negative side, these authors examine how those who oppose labels argue the same tenets of provision, awareness, and identity, but formulate arguments going in exactly the opposite direction as the pro-labellers. They argue, for example, that a label erodes a person's sense of identity and capacity for positive group identification in society at large, that it diminishes societal opportunities, including career options or advances, and the system around labelling works towards sustaining the system itself for the benefit of those who are operating the system rather than being a helpful resource to the vulnerable.

ii) Tensions around diagnostic means and labels

It is not just the act of putting a label onto a learner that is controversial, the means or vehicles that are used to produce these labels are under scrutiny as well. To rephrase, the very conceptual structure that is necessary to make diagnoses is under reconsideration.

A classic example from history of how measuring disability can be problematic is using the intelligence test as a basis for diagnosing intellectual impairment. Since the design and implementation of the very first intelligence test by Frenchman, Alfred Binet (1857-1911), for the Paris public school system, it was recognised that formally measuring intelligence is an act that has significant impact on an individual's self-identity and societal identity. Several studies support a positive correlation between IQ test scores and formal education and workplace performance (Perkins, 1995, p. 36). Consequently, IQ became a form of input to education, where those with higher scores were seen as more likely to succeed at school and in later life compared to those with lower scores (Martinez, 2000).

Intelligence tests have been re-evaluated and found lacking from many angles and even more so in relation to minority groups (Perkins, 1995, p. 37-42; Martinez, 2000, p. 18; Hayes, 2000, p. 188; Valencia & Suzuki, 2001, p. 282-285; Goodey, 2011, p. 4; Kaplan & Succuzzo, 2012, p.554 - 558). For example, the following aspects are being questioned: the political nature of the act of defining intelligence; the equivalence of the relationship between intelligence and IQ testing; the cultural validity of IQ tests; their construct validity or the extent to which the sample items represent an individual's body of knowledge; and, their task-driven nature and even their alignment with current brain science development. Another more recent challenge to intelligence tests is found in the work of Nobel prize winner, Daniel Kahneman, in collaboration with his late associate, Amos Tversky. These authors' ideas question the forms of rationality and systematic intelligence embedded in IQ test. Kahneman's work (2011, 2012) argues that this type of logic is not really the default system that people use when making decisions or when solving problems, but that people tend to rely on a more intuitive system of problem-solving that is full of shortcuts and biases. In other words, the intelligence tested in an IQ test is not necessarily the intelligence people use in everyday life.

A more current example relates to the editions of *Diagnostic and Statistics Manuals* (DSM) used in the Mental Health/Psychiatry domain, which up to now has been a powerful tool in determining diagnoses and assigning labels such as autism to learners with SEN. Some of the prominent mental health services are declaring their intentions to abandon the DSM-5 as a diagnostic tool for classification and research purposes (Voosen, 2013, p. 1). One of the key criticisms against the DSM editions is that they cluster together symptoms to form a set category, whereas these symptoms physiologically relate to a range of other categories as well. In other words, several of the same diagnostic categories share overlapping biological markers, which confounds clear research delineations from the perspective of accounting for biological markers when study the disorder.

The point I am making is that diagnoses in SEN settings are typically grounded in intelligence tests and/or DSM diagnostics. There is little point in basing extensive research on the grounds of diagnoses from these tools, if the tools themselves are being increasingly challenged as a scientific basis for understanding disorders.

2.4.3 Alternatives to labelling

Considering all the controversy around labelling, it is not surprising that new models have emerged that provide alternative frameworks for assessing the needs of learners with SEN.

2.4.3.1. Response to Intervention models

Some schools try to circumvent the processes of diagnosis and labelling by relying and focusing more on teaching and learning. An example of such an alternative is the three-tier approach of the Response to Intervention (RtI) model (Fuchs, Mock, Morgan & Young, 2003, p. 159). In RtI, learners are provided quality instruction and their progress is monitored. Those who do not respond appropriately are provided additional assistance and their progress is again monitored. Those who continue to not respond are thereafter considered for special education services.

2.4.3.2 Functional brain mapping

Perry and his co-workers (Perry & Pollard, 1998; Perry, 2006; Perry & Hambrick, 2008; Perry, 2009) have made brain imaging accessible to special education, in the form of a tool called the functional brain map. The tool is connected to a questionnaire that when completed produces a visual representation, showing which areas of the brain are underserved by neurological input. His work, like the IQ test, contributes to the invisible-visible shift by making what was previously invisible — brain structures and functions — visual and visible to educators. Since the brain map forms part of the learner's psycho-educational profile, I discuss its principles in more depth.

i) It fits within the Neurosequential Model of Therapeutics

The brain map developed from within the Neurosequential Model of Therapeutics (NMT). Perry and his co-workers developed NMT as a framework to explain the effect of trauma on children. They describe NMT as a developmentally sensitive, neurobiologically informed approach to clinical work, and not as a specific therapeutic technique or intervention. More recently, Perry and his team have been working on adapting NMT to school environments as *The Neurosequential Model of Education (NME)*. Although it is primary a model for trauma, Perry states that it could also be used for children with developmental delays; however, the time period for restructuring may take longer for a developmentally delayed child than for a trauma child. The framework has five core principles which are as follows:

- *The brain consists of interconnected systems:* NMT sees the brain as multi-systemic, involving different systems that interact and are interconnected. Four main anatomically distinct regions are referred to in the theory: brainstem, diencephalon, limbic system, and cortex. Various parts of the systems of the brain mediate different functions, for example, the cortex mediates thinking while the brainstem/midbrain mediates states of arousal.

- *The brain is organised in a hierarchy:* Most of the brain's organisation takes place in the first four years of life. The brain is organised sequentially in a specific hierarchy. The least complex features are located in the brainstem at the bottom, and the most complex are found in the cortex at the top. During development, the brain organises from the bottom to the top, meaning that the lower parts of the brain develop earliest.

- *The brain's development is influenced by neuro signals:* Monoamine neural systems (i.e. norepinephrine, dopamine, and serotonin) are very important in the brain. These project throughout all brain regions from the bottom up and have the unique capacity to communicate across multiple regions simultaneously and therefore provide an organizing and orchestrating role. As noted above, the organization of higher parts of the brain depends upon input from the lower parts of the brain. If the incoming neural activity in these monoamine systems are regulated, synchronous, patterned, and of "normal" intensity, the higher areas of the brain will organize in healthier ways. If incoming neural activity is extreme, dysregulated, and asynchronous, the higher areas will organize to reflect these abnormal patterns. Consequently, when these monoamine neurotransmitter systems are impaired they can result in a cascade of dysfunction from the lower regions (where these system originate) all the way up to areas higher in the brain. Put differently, when neurosystems in the brain are compromised and become abnormally organised, they lead to dysfunction.

- *The age of the experience affects brain organisation:* This model takes the history of the learner very seriously in so far as it tries to relate dysfunctional symptoms to the nature, timing, pattern, and duration of the developmental experience. For example, the very same traumatic experience will impact an 18-month-old child differently than a 5-year-old.

- *The brain stores memory:* NMT sees the brain as a historic organ. Structural and chemical changes in neurons allow for the storage of information or memory. As noted above, various parts of the brain mediate different functions. In addition, they also store information that is specific to the function of that part. This allows for different types of memory (cognitive — such as names and phone numbers; motor — such as typing or bike riding; or, affective – such as nostalgia). The brain stores information in a use- dependent fashion. The more a neurobiological system is "activated", the more that state (and functions associated with that state) will be built in. If these states persist, they will become traits. Consequently, the more frequently a pattern of neural activation occurs, the stronger will become its internal representation. The internal representation functions as a processing template through which all new experience is filtered. In the developing brain, memory states organise neural systems, which then become traits. A child will develop an atypical or abnormal pattern of neural activation when important neural systems are being over-activated during sensitive periods of developments.

ii) It is an assessment tool

Perry and his colleagues (Perry & Hambrick, 2008) state that the map is an oversimplification of the complexity of brain regions, yet it is useful to practitioners as an assessment/progression tool. It provides an approximation of the developmental/functional status of the child's key functions, helps establish the strengths and vulnerabilities of the child, and helps determine the starting point and nature of enrichment and therapeutic activities most likely to meet the child's specific needs. When used with the NMT philosophy, this functional map helps to document progress and to create a developmentally sensitive sequence to enrichment, educational, and therapeutic work.

iii) It is matched with specific interventions or therapeutic techniques

The NMT process helps match the nature and timing of specific therapeutic techniques to the developmental stage, brain region, and neural networks mediating the neuropsychiatric problems. Since the brain is organised in a hierarchical fashion, interventions have to start at the bottom and work upwards from there (Perry & Pollard, 1998). The idea is therefore to start with the lowest part of the brain related to the undeveloped/abnormal functions and to move sequentially up the brain as improvements are seen. This means that the first step in therapeutic success is brainstem regulation. A variety of patterning, repetitive somatosensory activities are advised as a way of reaching the brain stem. It is important to reach the brainstem in order to confront issues of self-regulation including arousal, impulsivity, and hyperactivity. Examples of such somatosensory activities include music, yoga, rhythmic breathing, drumming, and therapeutic massage. Once self-regulation shows improvement, the focus then has to shift to the limbic area to deal with relational-related problems. This can be done with play and arts therapies. After relationship skills have been established, a verbal and insight oriented approach can be adopted to work with the cortex areas of the brain. In short, brain function is strengthened through starting with repetitive rhythmic somatosensory experiences, then working towards establishing relationship skills, and lastly by strengthening reasoning.

iv) It has several advantages

The brain map tries to follow biological markers rather than social category constructions. Its use in education is not as clear as an x-ray of a broken bone would be to a radiologist or a doctor, but, nonetheless, I do feel that as educators we should start engaging with it to gauge its potential in practice. It is positive in that it:

- bypasses the act of labelling and diagnosing
- it is comprehensive and holistic
- it promotes growth, not stagnancy or fixed-ability
- it provides data that can be used to discuss the learner and inform classroom practices, making it suitable as a type of evidence-based practice
- it provides a well-rounded reference point of what to expect in terms of the learner's functions relative to home and school

v) It has challenges

The body is a physical organ and we have come a long way in understanding its mechanisms. Likewise, the brain is a physical organ that we are beginning to grapple with through neuroscience, but the real relationship between the brain and the mind still eludes us. The jump from the physical to the mental and the biological to the symbolic is not clear nor necessarily linear, yet Perry's work reminds us that brain functions influence all functioning — emotional, physiological, behavioural, and cognitive. We are still looking for clarity on whether intellectually disabled learners are just slower learners who need more time to learn or whether they actually learn differently. The brain map indicates that learners with SEN present with different brain structures and brain functions. Furthermore, the NMT philosophy suggests that learners with SEN do not just need more time but that they need very specific intervention, and in a specific sequence, depending on which area of the brain is under-activated. To emphasise, learners with SEN are developmentally different. Carlson (2010, p. 38-39) reminds us that schools that accept the notion that intelligence is dynamic, in this instance through restoring brain function, have to then assume far more complex roles than those who ignore the development of intelligence itself in favour of knowledge accumulation.

2.4.3.3. Dynamic Assessments

I have already discussed the rationale of using dynamic assessment (DA) as part of this study in Chapter 1. For completeness sake, I reiterate that DAs have proved particularly beneficial for learners with SEN (Gillies, 2014). DA is an umbrella term for types of formative assessment aimed at assessing the learning potential of learners (Feuerstein *et al.*, 2010; Le Beer, 2011). To illustrate DA, Vygotsky (1935/2011, p. 203-204) worked with two learners who were both 10 years old and who both had standardised test results that showed that they had the mental age of 8 years. He worked with one of the learners and together they solved problems that corresponded to the norm of 9-year-old children. Thereafter, he worked with the other learner and together they solved problems that corresponded to the norm of 12-year-old children. His conclusion was that the two children were not intellectually equal, as was suggested by standardised testing, in that the second learner had a higher learning potential compared to the first.

DA blends instruction with assessment, learning, and intervention. Consequently, DA forms a contrast to standardised testing, where the learners have to perform independently and are generally assessed by the assigning of a score to the product that they have produced independently of the examiner. One of the important goals of DA is to formulate recommendations for the development of learners' cognitive and learning functions via targeted cognitive intervention, based on the belief that these functions are flexible rather than fixed (Kozulin, 2014, p. 569; Feuerstein *et al.*, 2010). Moreover, Kozulin (2014, p. 556) also points out the strong relation between Response to Intervention (RtI) and DA. The higher a learner's potential to learn, the more likely that learner is to benefit from second tier intervention. On the other hand, a learner with a very low learning potential will most likely benefit more by remaining in or transferring to a SEN unit.

2.5 ACCESS THROUGH THEORIES OF LEARNING

Typically, DBR is locked into a specific learning theory, which makes the study of a wider range of theories seem superfluous in this regard. However, my intention to extend the literature beyond a single learning theory is very deliberate. I consider it necessary because of three existing states of affairs. The first relates to the discussion earlier that up to now research has shown that learners with SEN are not making significant strides in their learning, albeit in special needs centres or in more inclusive environments. In light of these data, since we know so little about how learners with SEN are actually learning, it would be premature to insist on a single theory before reviewing a broader scope of thinking around what learning is and how it happens.

The second relates to the implementation of the hypothetical learning trajectory (HLT) in the classroom, and in particular, the need to provide learners with support as they engage with activities drawn from the HLT. As was noted earlier, there is no pre-established winning formula for support. What a learner may need in terms of support in a given moment is often "a best guess" type of scenario, not only in terms of the strategy, but more specifically, in terms of the learner's response to the strategy. For this reason, support is certainly not a given constant but a continuous shift that is itself dependent on an exorbitantly large number of potential variables that can affect the learner during a given day. For example, the learner may have difficulty regulating his/her behaviour, or be sad about a relationship situation that developed at home or school and be in need of emotional support, or the learner may be struggling with content and require additional knowledge or strategies. Under these circumstances, educators need to be informed so that they can draw from a deeper pool of strategies and techniques rather than be theory bound.

A third reason is that although there are few (if any) universal principles of learning, reviewers are quick to compile and promote generic sets of best-practice teaching qualities. In current reviews of effective teaching (for example, Ko, Sammons & Bakkum, 2013, p. 2) it is clear that the descriptions used to delineate effective practices are drawn from behaviourist, cognitivist, and constructivist orientations. With this in mind, to be a good teacher a more rounded approach to learning philosophies is useful and necessary.

2.5.1 Introduction

There are myriad learning theories to be found in psychological literature. Below I elaborate on a select few that have had a significant influence, have contributed to paradigm shifts in the field, and are currently a prominent part of the debates in special needs education. Learning theories can be approached from many angles. Authors such as Porcaro (2011) consider the theories from a philosophical angle by comparing their ontological and epistemological dimensions. Then again, Sfard (1998) focuses more on the metaphors, linguistics, and meanings that emerge from different theories by distinguishing between a participation metaphor and an acquisition metaphor and by examining how these affect the perceived role of teachers, researchers, and learners. For the purposes of this study, I approach learning theories from the angle of instructional design. With this intention, I describe the psychological theories from the vantage point of how they depict teaching and learning in a SEN classroom, respectively. At the same time, I remain aware of the tension that psychological theories cannot necessarily be directly applied to classroom situations.

2.5.1.1 Behaviourism

Behaviourism has had, and continues to have, a profound influence on special needs education and is better known as direct teaching or explicit teaching. Behaviourism is the belief that behaviour itself is the appropriate object of the study of learning and teaching. Proponents maintain that it is in studying the cause and effect of behaviour that one is seen to be studying the cause and effect of learning itself (Moll & Slovinsky, 2009a). Accordingly, Burton and Moore (2004) define behaviourism as "the study of the observable, or outward, aspects of behaviour in relation to changes in the environment" (p. 61). Skinner (1964, 1974), who was one of the most prominent of the behaviourist theorists, did not deny the existence of inner cognitive states, but regarded them as irrelevant to analysing and understanding behaviour.

Behaviourism in a special needs classroom will typically present learning as an individualised (Burton & Moore, 2004) and a predictable process (Winn, 2008). Mathematical lessons will tend to follow a type of cookbook recipe (Kitchener, 1972) whereby complex mathematical tasks are broken down into procedures that should be followed in a step-by-step manner to produce a particular product. The steps involved are systematically explained and modelled by the teacher, then practiced by the learner, and thereafter tested by the teacher at the end.

The task of the teacher is to shape the learners' behaviour (or learning) through principles such as staged linear progression from simple to more complex tasks, prompts towards and reinforcement of effective behaviours with each step, and repetitive drill and practice built into the design (Burton & Moore, 2004; Bereiter, 2002). Furthermore, a behaviourist design model requires that the objectives of the study be clearly stated in any course; that all objectives are measurable and observable and that there is evidence of a change in the learner's behaviour. In respect to the validation of learning, behaviourists direct attention away from elements of understanding to performance and conduct, and learners are required to show their knowledge through observable outcomes. Regular feedback to the learners on how they are performing in respect to reaching these outcomes is very important.

Evidence from literature shows that behaviourism benefits learners with SEN. For example, authors (Steele, 2005, par. 10-15) argue that the predictability, the scaffolding, the deconstruction of the tasks by the teacher into manageable steps, and the support of reconstruction by, for example, graphical organisers, can keep learners who have difficulty with attention, organisation, and planning on tasks. Additionally, these techniques can keep learners with SEN from feeling overwhelmed by the demands. Likewise, the prompts, schedules of reinforcement, and repetitive practice can also be successful in dealing with behavioural problems that often accompany learners with SEN. Aside from the pedagogy of direct instruction, SNE has also adopted from the principles of behaviourism a wide range of tools and programmes such as the functional behavioural assessment, school-wide positive behaviour support, parental management programmes, and a number of behaviourist-based strategies used successfully with autism, like Applied Behaviour Analysis (ABA) (Mitchell, 2014, p. 4046 Kindle edition). Maag's (2014, p. 281-298) work considers some of the well-known historical attempts of applying behavioural theory to special needs education. He concludes that so much research in the 1970s and 1980s in special education schools considered the use of increasing and decreasing specific behaviours through behavioural techniques that the effectiveness of these techniques became an "established fact". He notes that the most researched topics for increasing behaviour were behaviour contracts and token economies, and topics for decreasing behaviours included time-out, response costs, and various schedules of reinforcement. However, more recent approaches such as NMT are challenging the effectiveness of these measures for specific populations of learners with SEN. To summarise, Table 2.1 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of behaviourism.

Table 2.1 Teaching and learning strategies from behaviourism

Philosophy	**Common Terms**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Behaviourism	Direct instruction Explicit teaching	Deconstructing materials into segments Precise example sequences Scaffolding Schedules of reinforcement/feedback Graphic organisers Time-out/Calm space Behaviour modification Visual schedules Repetition, drill, and practice Back-to-basics drive Rapid error-correction Applied Behavioural Analysis TEACHH	High	Burton & Moore (2004) Steele (2005) Maag (2014)

Table 2.1

Historically, researchers became increasingly interested in opening the "black box" by exploring conditions inside the learners and not outside them.

2.5.1.2 Cognitivism

The shift from behaviourism to cognitivism changed the meaning of learning, teaching, and research (Friesen, 2009). Whereas behaviourism defines learning as an enduring behavioural change achieved through stimulus and response conditioning, cognitivism looks at the way information is represented and structured in the mind. Likewise, teaching is no longer seen as modifying behaviour through reinforcement schedules but as the support of mental processing. Educational research is directed away from observing persistent changes in behaviour to formulating models of cognitive entities and their way of coding and decoding information.

The cognitivist framework is interested in how learners learn mathematics, both in terms of general conceptual frameworks that can be applied in any mathematical domain and in developing theories of learners' reasoning in specific areas of mathematics, for example, theories about multiplicative reasoning, algebraic reasoning, or statistical reasoning (Cobb, 2007, p. 25 - 27).

Work within the cognitive realm has helped special needs educators to be more mindful and pro-active with their identification and strengthening of how learners work with information as well as how they collect information, store it, interpret it, understand it, and apply it to learning situations. Being able to work effectively with information is fundamental to a wide range of skills of academic nature and social nature (Mitchell, 2014, p. 2746-2764 Kindle edition). For example, to read, learners have to decode; to write, learners have to be able to plan; to deal with social situations, learners have to anticipate responses. The focus on information has led to cognitive strategy training becoming an accepted part of special needs learning with specific emphasis on cognitive strategies, metacognitive strategies, and self-regulation (Brown, 1992; Ellis, 2005, p. 33-34; Mitchell, 2014).

Moll and Slovinsky (2009b) show the vast scope of the influence of cognitivism in education by describing theoretical variations in the different ways the revised interest in cognition proceeded. For example (see Moll and Slovinsky, 2009b), computational psychology, or the psychology of thinking, focused on mapping and defining cognitive structures; psycholinguistics became interested in conceptual domains; neuropsychology began to explore the embodied structures of thought; and, development psychology emphasised how cognitive structures change and develop over time, in both individual and historical perspective. Additional strands of cognitivism sought to use computer modelling to account for human behaviour, and artificial intelligence proponents became interested in developing computer programmes that could emulate human cognition. These many side branches produced key research into learning disorders that special needs educators have to manage, with the more popular ones being dyslexia, reading and writing inhibitors, and dyscalculia. To summarise, Table 2.2 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of cognitivism.

Table 2.2 Teaching and learning strategies from cognitivism

Philosophy	**Common term**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Cognitivism	Strategy instruction	Mnemonics Reading comprehension strategies Word recognition strategies Metacognition strategies	High	Ellis (2005) Mitchell (2014) Brown (1992)

Table 2.2

The first wave of the cognitivist revolution was followed by the rise of constructivism in the Anglophone world from 1970 to 1980. Constructivism fitted well into the climate of mentalistic psychology created by the cognitivist revolution. It also served as a source for ideas on how to make the break with behaviourism more complete (Moll & Slovinsky, 2009c.

2.5.1.3 Piagetian Constructivism

Classrooms that adopt a Piagetian model do not consider the behaviourist way of transmitting mathematical knowledge to learners in the classroom to be an effective form of teaching. Cobb (2007, p .5) argues that in this type of constructivism the goal of instruction in a special needs classroom is not the act of communicating knowledge to learners, thereby telling them what to do and how to do it, but rather to support learners' own active constructing of knowledge.The central tenet of the constructivist metaphor is that humans are knowledge constructors (Mayer, 1996; Friesen, 2009). Knowledge is no longer seen as a product compiled by the teacher and transmitted to the learner; instead, knowledge is a process of formation executed by the learners themselves.

To support the learners' construction, learners play the primary role in organising their knowledge and in sense-making by interacting with their environment and by working through cognitive dissonance as it emerges from this interaction (Ginsburg, 1985). For this reason, learners need to question, experiment, and discover mathematical relationships and principles for themselves. Consequently, mathematical content in the classroom should not be presented as static and fixed, but learners need to work in ways in which their knowledge is constantly changed and transformed to meet challenges and contradictions. Moreover, organising knowledge through active construction means developing a network of connections that will support a much broader and holistic knowledge platform. To this end, knowledge should not be presented in small insular fragments, but knowledge should be connected and elaborated to learners' past knowledge and experience, to the learners' interactions with their environments, and to personally constructed meaning.

Special needs educators question how conducive to learning the "free spirit" embodied in this type of constructivism is to this cohort when placed against the backdrop of their challenges and variances. The states and traits that accompany the syndromes typically found in a special needs cohort may at times directly interfere with the learning principles promoted by constructivism. For example, intellectually impaired children may present as very passive and be reluctant to display the initiative towards learning and exploring foreseen by constructivism. Children with sensory difficulties may not gain as much from direct interaction with the environment as they should to optimise their learning, and children with regulation difficulties and/or attention deficits may not be settled enough to explore learning and sense-making in such an open-ended and independent manner. To summarise, Table 2.3 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of Piagetian constructivism.

Table 2.3 Teaching and learning strategies from Piagetian constructivism

Philosophy	**Common term**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Piagetian constructivism	Active learning (learner driven)	"Hands on learning" Concrete, manipulables Pure discovery-based learning Integrated learning	Limited	Mayer (1996) Ellis (2005) Tobias (2009)

Table 2.3

In Piaget's defence, his theory of learning was never developed with learners with SEN in mind but with his own middle-class Swiss family. Vygotsky, however, did work directly with learners with SEN. A key learning principle derived from Vygotsky's work is that knowledge is constructed socially through negotiation and mediation with others (Jaworski, 1994). In other words, where Piaget relied on the unfolding of a biologically driven sequence to spur along cognition, Vygotsky relied on the interactions of a culturally, historically, and linguistically rich context. Kozulin (2013) reminds us that theorists often draw on their own life experiences. For one thing, Piaget was a boy scientist who observed biological organisms acting on their environment. Thereafter, he argued that thought is a form of action, that is, thought starts with a physical action (sensory motor) and then transforms and gets internalised as a mental action (operations). Piaget also believed that a child's thinking is different from an adult's thinking. On the other hand, Vygotsky was, from early childhood, interested in language and culture. Later in his life, after one month at medical school, he changed his studies and became a lawyer. He argued that cognitive processes are socio-culturally built, and although they developed from natural processes such as memory and perception they are reshaped by cultural tools. Thoughts are therefore not activities themselves, but active acquisitions of cultural tools. Vygotsky also believed that Piaget's "child-like thought" was a mere illusion, as thought was being influenced by society from the first day of life. He maintained that our thinking is a product of our socio-cultural existence and cannot be separated from it.

2.5.1.4 Social Constructivism

As a result, it was Vygotsky and other social constructivists who began to consider the social nature of knowledge and the social formation of the mind in so far as knowledge is mediated and collaborated and how it is contingent on language and other semiotic devices. In short, how construction occurs in dialectical relationships (Loong, 1998; O'Donnell, Reeve & Smith, 2012, p. 321). A metaphor employed by social constructivists is that learning is social negotiation and that learners are social negotiators (Mayer, 1996). Learning is acknowledged not only as an individual process but also as a social process that requires adult guidance and peer collaboration. This view considers how there are certain social arrangements and social structures that augment and support human learning. De Valenzuela (2014, p. 300) notes that thus far the social cultural views of learning have had little significant influence in special education. Yet, special needs educators are increasingly being encouraged to consider interpersonal participatory activities that will enable relational interchange, inter-subjectivity, and conversational negotiation (Mitchell, 2014, p. 1167 Kindle edition).

By way of applying social constructivist principles to mathematical learning, special needs educators are to help learners create and negotiate meaning through a rich language environment by "talking mathematics". For discourse to be effective in a SEN classroom, the nature and quality of the discourse are significant. For example, evidence suggests that learners with SEN require a combination of perceptual, conceptual, connecting, strategic, and affective content in dialogue (O'Donnell, Reeve & Smith, 2012, p. 321). Moreover, the nature of the dialogue must be such as to support the learners' current sets of knowledge and skills, and to allow learners to cognitively advance from there. To illustrate, De Valenzuela (2014, p. 305) encourages teachers, especially those who work in segregated sections with learners with SEN whose communicative abilities are still emerging, to use instructional discourse. She (de Valenzuela, 2014) describes the key aspects of instructional discourse as "the strategic use of questions designed to deepen learners' thinking about ideas, rather than testing questions with a predetermined correct answer; teachers' comments aimed at stimulating learner reflection, rather than information transmission; and the natural evolution of dialogue without a pre-set script" (p. 305). She adds that instructional conversation is about relating formal school knowledge to the personal/community knowledge of the learner. Historically, Tharp and Gallimore (1988) coined the term "instructional conversations" (p. 100), to divert educators' practice away from the traditional script of teacher's initiation, learner response, followed by teacher's evaluation.

From a well-being perspective, a social constructivist setting allows disabled learners opportunity to connect to their peers and to receive social and emotional support from them (O'Donnell *et al.*, 2012, p. 292). Cozolino (2013) expresses in his book how critically important positive connection and relationship-building opportunities are against the typical histories of failure and subsequent shame and rejection that these learners have experienced in their lives. Furthermore, social constructivism also broadens the scope of behavioural interventions by considering how challenging behaviours may originate from the dynamics between learners and their environments, instead of only looking at modifying an individual's behaviour. (De Valenzuela, 2014, p. 309). Table 2.4 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of social constructivism.

Table 2.4 Teaching and learning strategies from social constructivism

Philosophy	**Common terms**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Social constructivism	Interactive learning: Mediation Dialogue Group work	Collaborative learning Instructional conversations Peer mediation Environment adjustments for behavioural management Using social networking tools - Facebook	Limited	O'Donnell et al. (2012) Cozolino (2013) De Valenzuela, (2014)

Table 2.4

It is important to realise that there is a significant distinction between how we understand learning and development in terms of Skinner, Piaget, and Vygotsky. Vygotsky (1978b, p. 80-81) described the distinctions as follows: For behaviourists, learning is development. As learners with SEN learn to associate a stimulus with a response, and to master a reflex, they are developing simultaneously. For Piaget, development happens external to learning and it is a prerequisite to it. Put differently, learning uses the achievement of the development of a learner for its ends. For Vygotsky, learning and development are separate processes, which reinforce one another. Development allows learners with SEN to learn, and learning allows learners with SEN to develop.

Another key point is that constructivism is described as moving from the individual mind to the social, whereas social constructivism is seen as moving from the social to the individual. In other words, in social constructivism the individual consciousness is built from the outside in and not from the inside out as in Piagetian constructivism. However, there is another school of thought that entirely abandons the notion of an individual consciousness being constructed by embracing a paradigm where consciousness is situated within the social context. This view is known as situated social cognition.

2.5.1.5 Situated Cognition

Historically, the situated social cognition view is part of the second wave of the cognitive revolution. As was noted previously, the first wave of cognitive revolution focused on the internal mechanisms of thinking. Cognition was deemed intrapersonal or situated inside the individual. Theorists from the second wave began to explore the interpersonal nature of cognition instead (Moll & Slovinksy, 2009c). To this end, they began to focus on how meaning can be embedded in cultural interactions, communications, and artefacts. The key point being made is that there was a deliberate shift from the first wave of the cognitive revolution with the individual as the unit of analysis to the second wave where the unit of analysis became the social-cultural setting and its practices, or how an individual acts in a particular cultural context (Lave, 1988, p. 63-68). Since the situated cognition paradigm is not concerned with how we internalise a concept intrapsychologically, but instead with how we as novices begin to experimentally imitate and eventually adapt ourselves to the larger culture's use of interpsychological tools, the learning process in this model is enculturation (Lave, 1996).

To facilitate the process of enculturation in mathematical lessons, situated cognitivists apply their principle of contextualised learning and their metaphor of a cognitive apprenticeship. According to the principle of contextualised learning, how knowledge is learned cannot be separated from how it is used in the world. In other words, knowing and doing is linked (Brown, Collins & Duguid, 1989, p. 32). Consequently, learning tasks, for example, mathematical problems, should be placed within experientially real frameworks that have social-cultural-political affordances and constraints, thereby allowing for the construction of meaning to be tied to specific contexts and purposes.

With the metaphor of a cognitive apprenticeship in mind, situated cognitivists follow a more natural approach to learning in the mathematics classroom called "learning-in-practice". The metaphor refers to the instruction design principle that activities of learners must resemble the activities of practitioners working in the mathematics field. Likewise, learners become craftsmen who are learning the trade from their master. This strong linking of the development of human consciousness with human activity is further developed in the activity theory of Leont'v (1978). In this view, learning is linked to the purpose of the activity, the tools the community use for the activity, the rules the community endorses for doing the activity, and the cultural norms that apply to the activity, for example, labour divisions.

Adopting the situated cognitivist's view of weaving together cognition and context (Lave, 1996, p. 5), could help learners with SEN to appreciate the potential of mathematics as a critical tool for analysing important issues in their lives, communities, and society in general (English, 2007).

Equally important, is the shared concern amongst special needs educators and situated cognitivists over what happens to learners with SEN when they leave school. Special needs educators want learners to gains skills that will enable them to function as independently as possible in society after school. For this reason, special needs educators tend to share ideals from fields such as occupational therapy in wanting to establish the maximum level of sustained functionality for learners with SEN in community life after school. For example, preparing learners for assisted living programmes, using public amenities like catching a bus, and gaining basic forms of employment are common endgoals in special needs environments. Certain authors have pointed out that there is often a serious mismatch between what we teach learners at school and what is required of them once they leave school. For example, Resnick's (1987a) work examines how cognition deemed significant by the schooling system and cognitions that are marked relevant to society are quite at odds in their natures. She argues that whereas schooling promotes individual cognition and performance, society uses shared cognition; likewise schooling promotes pure mentalism (thought) but society values tool manipulation; schools function with decontextualised symbol manipulation, whereas society utilises contextualised reasoning; schooling promotes generalised theories and skills yet society is situation-specific. To help learners make the transitions from school into society more easily, researchers have tried using the contextualised learning principle of situated cognition to adapt vocational training programmes for learners with SEN (Lave, 1996). Like social constructivism, situated cognition can be useful to learners with SEN by promoting identification with a group and by nurturing a sense of collective efficacy (O'Donnell *et al*., 2012, p. 280) that extends beyond the borders of school into broader society. To summarise, Table 2.5 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of situated cognition.

Table 2.5 Teaching and learning strategies from situated cognition

Philosophy	**Common terms**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Situated Cognition	Knowledge needed outside of school	Vocational training electives Functional mathematics and literacy Authentic learning experiences Integrating occupational therapy recommendations into EAPs	Moderate (for older learners)	Leont'v (1978). Resnick (1987a)

Table 2.5

2.5.1.6 Distributed Cognition

Assistive technologies are increasingly being used as tools to aid learning in special needs classrooms. Assistive technologies are a growing market and provide a range of products that can support learners with SEN in many different ways (Dell & Newton, 2014, p. 703). It is time for SNE to give serious thought to how these devices work together with cognition. Roy Pea (1985, 1993) coined the term "distributed cognition" to emphasise that the mind never functions alone but is distributed across persons as well as symbolic and physical environments. Distributed cognition views the combination of people and tools as a cognitive system. Knowledge is thus not the property of the individual but is found in the network between the individual and the social-physical aspects of the environment. Put differently, learning is distributed or "stretched over" an extended cognitive system, which may include the individual, other people, artefacts, and tools. Accordingly, distributed cognition moves the unit of analysis to the larger cognitive system and finds its centre of gravity in the functioning of the system (Nardi, 1996, p. 77-78). Pea's work is complex and controversial from a traditional perspective. Yet, it reminds stakeholders to pay more attention and to think more broadly when analysing the value and the impact of technologies on learning. To summarise, Table 2.6 provides an exemplar list of instructional strategies for use in SEN classrooms that emerged from within the work of distributed cognition.

Table 2.6 Teaching and learning strategies from distributed cognition

Philosophy		**Examples of Strategies**	**Acceptance and Use**	**Authors**
Distributed cognition	How assistive learning devices influence cognition	Increase in assistive technologies in the market, for example: Alternative communication Text to speech Speech to text	Limited (use of assistive devices is accepted, but theory in this regard is still underdeveloped)	Dell & Newton (2014)

Table 2.6

2.5.2 Neuroscience

Neuroscience models are generally criticised for being far too removed from education to be helpful; however I find Perry's work an exception in this regard. Perry and his colleagues have put much effort into integrating his model into educational practice. Goswami's (2014, p. 323-330) analysis of the work of neuroscience in learning contains findings that corresponds very closely to Perry's work discussed earlier, such as the importance of rhythm or oscillation in learning, and how a disrupted frequency could explain co-morbidity in developmental learning difficulties. Likewise, there is neuroscience's hypothesis that basic sensory information could form the basis of core conceptual knowledge, and in particular the motor system, which is further substantiated by authors such as Murdoch (2010, p. 858). In addition, Goswami (2014, p. 326) relates the sensory-motor-higher-cognitive processes, which links back to Piaget's idea of thought developing from sensory-motor actions, and the need for some learners to be active and "doing" something in order to learn. Yet, brain imaging is also showing that sensory-motor systems are not replaced by symbol systems as Piaget believed, but that symbolic knowledge always depends on the activation of multiple networks, including sensory and motor networks. These findings lend credence to the instructional design philosophy of UDL, which argues for the activation of multiple networks during lesson activities. Historical intervention, such as those undertaken by Séguin, and modern interventions like neuro-science both support a more holistic approach to learning, which re-affirms the physical-intellectual relationships and the emotional-cognitive influence. They serve to remind special needs educators that the teaching and learning of learners with disabilities is not just a cognitive, performance-based drive (OECD, 2007, p. 18). To summarise, Table 2.7 provides an exemplar list of instructional strategies for SEN classrooms that emerged from within the work of Neuroscience.

Table 2.7 Teaching and learning strategies from neuroscience

Philosophy/paradigm	**Common term**	**Examples of Strategies**	**Acceptance and Use**	**Authors**
Neuroscience	"Brain science"	Rhythm Somatosensory activities Relationship development	Moderate (high interest, application still being explored)	Perry & Pollard (1998) OECD (2007)

Table 2.7

2.5.3 Which learning theory for learners with SEN?

Currently, there are very few, if any, universal principles of learning. From a theoretical research perspective we have myriad learning theories, which illustrate that human cognition is multidimensional and how each major theory expresses different aspects of its complexity. For example, from a certain cognitivist perspective learning could be seen as recall through input-processing-storage-output memory mechanisms, from a neuroscience perspective learning is change in biochemical activity, for the behaviourist learning is a rather permanent change in behaviour and behavioural dispositions, and depending on the form of constructivism one uses, learning can be seen as conceptual change, as social negotiation, or as participating in an interactive and interdependent activity (Jonassen, 2009, p. 15-17). The situation seems to describe the story of the blind men trying to describe an elephant to one another by responding to the part of the elephant that is right in front of them and most readily accessible to their touch.

Like the task of the blind men trying to describe an elephant and coming up against one another's different and contradictory perspectives, we know that there are inconsistencies in how theories explain learning, and that theories will deliver differential measures of effectiveness of learning depending on a range of other factors such as the cohort, the context of learning, and available resources. Moreover, we are cautioned by numerous authors that theories of learning are not necessarily directly applicable as theories of teaching. Consequently, when theories of learning are applied to teaching, they may present with unintentional instructional consequences in classroom situations.

Special needs education is caught up in the ideological separation between the instructivist (behaviourism) and the constructivist-types (cognitive constructivism, social constructivism, cognition, situated cognition, and to a lesser extent, distributed cognition). We have two camps pitted against each other with each group trying to capture the flag of the other. Perhaps the intensity of the debate on both sides can be understood when considering that the constructivist-instructivist debate has been ongoing since the time of Plato and Aristotle (Moll & Slovinsky, 2009a). Plato and Aristotle were involved in an empiricist-rationalist argument in philosophy that translated into the nurture-nature debate in psychology and has since progressed in education as the constructivist-instructivist debate. Historically, it has been an ongoing and lengthy debate.

For the most part, explicit teaching approaches and cognitive instruction, particularly in the form of strategy training and intervention, are well-established in special needs education (Ellis, 2005, p. 45; Taylor & MacKenney, 2008, p. 152-153; Mitchell, 2014). On the other hand, constructivism is less accepted, and in some cases, strongly discounted.

> There is very limited evidence to support the use of constructivist approaches for learners with special needs and the approach is clearly at odds with what is known about effective instruction for such learners in basic skill areas. On the other hand, there is clear and convincing evidence for explicit teaching approaches to instruction (Wheldall, Stephens & Carter, 2009, par. 5).

At the same time educators may not be ready to return to previous states of affairs in full measure either. For example, Harris & Alexander (1998) state:

> Like Dewey, we have seen first-hand the toll that a forced-paced, decontextualised approach dominated by skills-based materials and curricular takes, not only on learners but also on their teachers. Lost opportunities for developing meaningful literacy and understanding; boredom and lack of relevance of school to learners' lives; overwhelming emphasis on factual material resulting in inert, ritual knowledge and a focus on innate ability rather than effort and development are among the shortfalls of a skills and workbook dominated approach to instruction. This situation, unfortunately, continues in many schools and classrooms across our nation and continues to be an important catalyst for change (p. 117).

Under these circumstances, both sides are defending their camp against the criticism being generated by the other. Authors such as Karpicke and Blunt (2011) and Rowe (2006) are arguing that direct teaching methods provide better learning outcomes than constructivist techniques but, more importantly, that direct teaching is meaningful to learners, and that it involves construction elements such as the reconstructing of knowledge during retrieval. In other words, they are dismissing the "kill-joy", passive, dull, boring, old-fashioned, and limiting learning image that is associated with direct instruction in some circles. For this purpose, they argue against direct teaching being "passive" and instead portray it as a dynamic and active form of learning.

There are several responses from constructivists to their critics on the subject that they are not delivering on their promise of producing mathematical results. For the purpose of demonstrating results, constructivists are calling for stricter research criteria and research delineation to be in place (Meyer, 2009). For example, researchers need to consider that constructivism assumes many different forms, which in turn serve different pedagogical functions (Golding, 2011, p. 467 ff.). With this in mind, constructivism should not be broadly evaluated, but more attention should be given to which constructivist format yielded which type of results. In other words, the style of constructivism the researcher is using should be clearly stated in the study and in subsequent studies on the study, as different forms of constructivism may yield very different results when used with the same research problem in the same context.

Equally important, constructivist ideals should be measured using constructivist instruments and assessment techniques. Schwartz, Lindgren and Lewis (2009, p. 51) provide numerous examples of where empirical research used non-constructivist assessment to measure constructivist beliefs. A mismatch between ideology and instrumentation may yield unintended data biases. These authors acknowledge that the complexity of the constructivist setting provides a real challenge for instrumental design because of its focus on holism and interdynamics between teacher, learner, and task.

It must also be remembered that the interpretation of data, when comparing constructivist and empiricist studies, may require a deeper analysis than an immediate response to the improvements shown in a particular study. To explain, Schwartz, *et al.* (2009 give examples of study outcomes which show that "constructivism *writ large* yield more favourable results than constructivism *writ small" (*p. 57). Accordingly, Schwartz *et al*. (2009) state that the types of study favouring direct instruction "tend to be small-scale, use limited measures, and time horizons, pick 'skill acquisitions' or simple concepts as the learning goals, and distort the constructivist control conditions" (p. 34). For example, Sullivan (2011) points out how studies in Australia show that for the most part learners are performing reasonably well against international standards and tests, which demonstrates that learners gain from direct instruction. Yet, at the same time there is a steady decline of interest in pursuing mathematics as a university subject. One suggestion is that explicit teaching may be raising results (or producing a certain form of evidence), but the long term effect suggests that it may be losing its customer base as learners tend to lose interest and motivation in the subject. This example illustrates how the relevance of a study can no longer be interpreted by only focusing on the immediacy of the results, but should be analysed from multiple dimensions when possible, including influence over an extended time period.

On balance, I concede with Tobias (2009, p. 340) that there is an extensive amount of persuasive rhetoric coming from both the constructivist and the instructivist camps, and a collection of mixed evidence from the research. A key point for educators is that evidence from the instructivist camp is showing more convincing immediate gains for learners with special needs in the area of mathematics. I also concede with Tobias that the core debate, the one that will help settle the issue of the real gains of the different philosophies in relation to the learner with SEN, is also the one that is still missing from the debate. The core issue he is referring to is a better understanding of cognitive processes in relation to constructivist and instructivist rhetoric. Do constructivist and instructivist learning share the same cognitive processes or do they evoke different cognitive processes? How would the intensity and frequency of the cognitive processes of each approach differ when compared to the other? A deeper understanding of the cognitive processes involved may very well change the nature of the debate. Yet, our understanding of how learning occurs, and our ability to assess the effects of different learning environments are still emerging fields. On the whole, we require a much deeper understanding of the physiology of learning as well as how the brain-mind divide is bridged.

Until we know more, special needs educators are encouraged to respond to the juxtaposition by keeping an open mind towards constructivism. There is a general agreement that there is no "one model" for special education. Correspondingly, the mandates for educators from literature in Australia and New Zealand are to balance teaching between the two approaches and to pursue evidence-based practices (Ellis, 2005; Mitchell, 2014). I concede that these processes sound reasonable on paper, but they can easily conceal a maze of complexity when trying to implement them at grassroots level. I will explore the idea of balancing and evidence-based practice in special needs education in more detail, with the aim of showing the intricacies, complexities, and even naivety of these mandates.

2.5.2.1 Balancing Constructivist and Instructivist pedagogies

Different authors show how balancing constructivist and direct instruction methods can be approached and interpreted from multiple angles. Accordingly, some authors pay attention to the attributes of the task, others focus on the attributes of the learners, and still others concentrate on the attributes of epistemological categories.

i) The attributes of the learners

Balancing could mean integrating constructivist and explicit foci during lessons, depending on the needs of the learners with SEN. Some literature (Ellis, 2005, p. 50; Rowe, 2006, p. 2; Tobias, 2009; Muijs & Reynolds, 2011, p. 50) suggests that constructivist teaching is better suited to intellectually abled learners and socially stable learners, including learners from advantaged backgrounds, first language speakers, and learners with a reasonably strong prior domain knowledge. These authors argue that direct teaching methods, on the other hand, are well suited to younger children and children who are experiencing some form of disadvantage whether it be social or emotional in nature. Examples include situations when an essential strategy, skill, or concept is being employed for the first time and for learners who are: falling behind their peers as a result of too little teacher direction, from poverty-stricken home environments, at risk of cumulative difficulty because they learn more slowly than their peers, losing confidence and interest when trying to work independently, and for learners with analytic and auditory learning styles.

ii) The attributes of the task

In terms of task attributes, the nature of the task itself may be more suited to a particular learning structure. At times, the task may be setup so that learners may have to work completely on their own, as in Piaget's notion, or they may have to work socially as a group and be pulled along by more capable others within the ZPD. Likewise, the task may allow learners to become apprentices or may require direct teaching.

Some authors argue that balancing is a matter of sequence more than a matter of task attributes. To explain, direct teaching comes with the primary aim of helping learners establish a reasonably strong domain knowledge before moving on to higher-order cognitive processing and more open-ended knowledge tasks (Tobias, 2009; Ko, Sammons & Bakkum, 2013).

iii) The attributes of curricular goals and knowledge types

Although the balancing approach is inviting in its eclectic nature, its intuit logic of connecting across domains, and its assumptions of commonality across different knowledge types, I would argue that it is also slightly naive in its lack of expressing the power divisions that lie amongst different education models of school-based curricula and their respective goal specifications. To clarify, Skillbeck (1984, p. 30) discusses how school-based curricular decisions have historically been biased towards one of four educational models. The first is where the focus of the curriculum is on the structure of the forms and the fields of knowledge. The focus is on the knowledge that accompanies that subject domain and in helping the learner work with, organise, and apply the knowledge of a structured discipline. The second is about the pattern of learning activities set out for the learner. The focus here is not on the knowledge component per se but on the learner being able to participate in, engage with, and experience set activities. This view encompasses a developmental aspect and a good example of this kind of thinking is found in *The Hadow Report: The Primary Years* (Board of Education, 1931):

> Applying these considerations to the problem before us, we see that the curriculum is to be thought of in terms of activity and experience rather than of knowledge to be acquired and facts to be stored (p. 93).

The third curriculum in Skillbeck's typology (1984) is more about a chart or map of the culture with attention given to establishing reflections/elements of society in the classroom and on preparing the learner for later entry into society. The last category is a technical and rational problem-solving progression where learning objectives are identified, experiences are selected to fulfil these objectives, the experiences are organised to project scope and sequence, and there is an evaluation to measure the level of attainment. A loose correspondence can be drawn between Skillbeck's typology, for example, behaviourism and its historical focus on knowledge advancement, Piagetian constructivism and experiencing learning through activity, and situated cognition and the goal of preparing learners for life in their communities.

The first thing to remember is that on a general and broad level of practice, stakeholders will be agreeable about the necessity of incorporating all of these aspects into a child's journey while at school. Yet, Norwich (2013, p. 1404 - 1425 Kindle edition) argues that when trying to implement these typologies into a school curriculum, particularly with regard to details of delivery, several strong tensions upset the balance of compatibility. For example, those in the knowledge camp are accusing the social-emotional-wellbeing group of undermining education by diverting focus away from the intellectual challenge. By the same token, social competency advocates argue that the knowledge of today has a limited shelf life and that it will most likely be outdated and irrelevant in the future. In consequence, they want the focus to be on how to access knowledge and create knowledge through communication, thinking skills, and creativity. In this argument, the social camp is pushing for knowledge in general or skills competency, without becoming too caught up in the nitty-gritty of the knowledge itself that is in the domain specifics of the subject. This is in turn is balked at by subject purists who see intricate knowledge and structural conceptualisation of the subject domain as the launching pad for future developments. Then again, the learning orientation and its technical-rational outlook is all about effectiveness and how to measure effectiveness.

The point being made is that there are target-driven agendas and unresolved fractures around the nature of knowledge, which affect the underlying processes in which learners engage and the pedagogical practices that are valued. These fractures run deep and are not that easily patched up by an academic mandate to "share and play nice", that is "to balance".

iv) The attributes of autonomy and control between teachers and administrators

In arguing for balance, we have to consider how much capacity and autonomy special needs educators may have in deciding and creating their own models of balance. The autonomy of teachers is constrained and/or facilitated by a number of factors such as their own professional development, personal belief systems, and by organisational parameters such as whether the school endorses a top-down or bottom-up approach to curricular matters.

As much as the "balancing act" between instructivist and constructivist ideologies is left wide-open to interpretation, the idea of evidence-based practice is also controversial.

2.5.2.2 Use Evidence-Based Practice

Evidence-based practices, also called evidence-informed practices, are spreading on an international, national, and local level throughout societal structures. In education, they are supported in several national and international influential policy movements, for example, the *No Child Left Behind Act* (2002) in America and the current *Visible Learning* (n.d) drive in the Northern Territory of Australia. In short, evidence-based practices advocate for randomized controlled field trials as the gold standard in education (Biesta, 2007, p. 3). It is important to realise that one of the biggest challenges that education still has is the persistent gaps between research and practice and research and policy. Proponents of evidence-based practices maintain that they can achieve a double transformation through their movement that will both align educational research and educational practice to scientific knowledge. They argue that the scientific knowledge produced by evidence-based practices will prove to be effective, efficient, and superior to pre-scientific opinions that educators tend to rely on to inform their practice (Biesta, 2007, p. 2). With this in mind, they are very dismissive of other types of research.

Although prima facie analyses may suggest that these statements are reasonable and achievable, one only has to scratch the surface to fall into a melting pot of contradictions that emerge from the evidence-based practice movement.

I am concerned that there is little said about the rivalry over the diversity and competitiveness of research philosophies for education. What counts as evidence, or the type of evidence researchers decide to collect (and the type of evidence they decide to discard), and the methods practitioners employ to collect the evidence are all derived from philosophical positions which (re)define the meaning of research and the meaning of learning.

It is important to realise that in the movement's search for science and evidence-based practices it is trampling underfoot several issues that are significant for those who consider education first and foremost as a human enterprise and then as a scientific one. Proponents of evidence-based practices are forgetting that evidence does not define education, but that education defines evidence.

First, evidence-based discourses have usurped the role of science from being descriptive in nature to being prescriptive in their approach (Biesta, 2007, p. 5). This is not compatible with education, given that evidence is technical in nature whereas education is largely normative and democratic in nature. Put differently, showing that it works does not necessarily make it educationally desirable. Yet, evidence-based practitioners display little hesitation in overruling this notion by prescribing to educators what counts as evidence, forgetting that the decision of what is educationally desirable and what is not are really value judgements and not scientific ones. Simply put, evidence cannot determine larger learning principles and values. It can evaluate ways of reaching learning outcomes, which are derived from or based on principles, but it cannot provide those principles by itself. Consequently, authors such as Oancea and Pring (2008) argue that the question of "what works" should be replaced by "*what is appropriate* for the learner under the current circumstances" (p. 15).

Second, evidence has a relatively small and non-linear influence on larger decision-making processes. When deciding policy, preference is typically given to contextual factors such as political priorities, historical and cultural notions of what counts as worthwhile knowledge, availability of resources, trust of teachers' levels of professionalism, and a host of other variables that are typically more powerful in swaying decision-makers than evidence itself (Gough, Tripney, Kenny & Buk-Berge, 2011, p. 13).

Third, since 1990 some schools in America and since 2013 schools in the Northern Territory of Australia have experienced governmental contracts with external providers to implement school-wide reform programmes to bring about evidence-based practice. The notion of whole-school reform is in line with international trends. For example, Ko, Sammons and Bakkum (2013, p. 11) point out how best-practice in the 1990s in England focused mostly on the teacher-learner-subject triad, but how current focus is on providing consistent learning and teaching across the whole school. In this regard, authors such as Rowe (2003) argue that teacher effectiveness is the factor that still makes the real difference in schools.

In reality, whole-school reform by external providers could mean that teacher-based and school-based evidence is replaced with external evidence. For this reason, a criticism against these types of programmes is that they rob schools of professional autonomy and localised control (Peurach, Glazer & Lenhoff, 2012, p. 52). Peurach *et al.* point out (2012) that the real issue is not related to the making or buying dichotomy, but is rather the school's capacity for collaborative learning amongst stakeholders. They argue that a school who decides to "buy" will at some time have to "make" it work, by adapting bought resources (p. 52). Also, the school who decides to "make" will at some time have to buy resources from multiple providers (p.53). I would like to see evidence-based practices respond to teachers as semi-autonomous professionals, not by overriding their decision-making capacity or by being dismissive of their professional practice, but as Peurach *et al.* suggest, by blending their experiences with evidence through the collaborative learning processes and in the discussion of how adaptations to local contexts should be made.

In the final analysis, I concede with the Evidence Informed Policy and Practice in Education in Europe project (Gough *et al*., 2011, p. 13) that the strategies around working with evidence, and in particular implementing the use of evidence, within education are still immature and largely undeveloped. I also agree with authors such as Biesta (2007) that we should extend our questioning in these areas beyond asking "Is it effective", to asking the better question of "It is effective *for*…?" (, p. 5). The "effective for" then needs to be expanded to include questions such as effective for which content, effective for which cohort of learner, effective over which time frame. Closer attention needs to be given by schools to the kind of questions that Ko, Sammons and Bakkum (2013) are asking in an effort to give stakeholders a chance to lay the foundations for teaching and learning through professional debate, rather than to be given the gold standard as a closed-off entity. For example, their definition challenge (Ko *et al*., 2013, p. 4) contains provoking questions that have thus far been neatly side-lined by evidence-based practices. Ko *et al.* challenge the education community to consider how they are going to define effective teaching by deciding if effective teaching should be constrained to factors residing in the classroom only, whether effectiveness is best viewed in relation to academic outcomes only, whether other educational factors should be looked at, by specifying at what time outcomes should be looked at, and who is best equipped to judge the effectiveness of teachers in this regard. These delineations are even more important in SEN environments, where there is an underlying tension to prepare the learners for life outside of school. On the whole, I see evidence-based practices as serving politicians and their needs for standard-setting coming before educating learners.

2.6 SUMMARY OF THE CRITICAL FEATURES OF LEARNERS WITH SEN TO ACCESS MAINSTREAM CURRICULA

By and large the education-for-all movement is well-established in schools. Research and practice worldwide suggest that the key solutions to the *Access to the Curriculum Dilemma* for learners with SEN are as follows:

- train all teachers to become specialists (Section 2.3.2)
- differentiate the curricula, using reasonable adjustments in consultation with others, including consultation with learners with SEN themselves (Section 2.3.3)
- make teaching and learning multi-modal, for example, through integrating UDL principles into lesson plans so that all learners can benefit (Section 2.3.3.1)
- use LSAs as a last resort (Section 2.3.4)
- balance learning theories, in particular direct teaching with constructivism (Section 2.5.2.1)
- shift to evidence-based practices (Section 2.5.2.2)

2.7 THE ROLE OF FEUERSTEIN IN THIS STUDY

What role does Feuerstein play in all this? First, let's summarise what has been said by the reforms thus far. Due to the hard work of the social model in particular, learners with SEN have the assurance that they will not be denied a place in mainstream, and that they will not be denied the opportunity to participate in a common curriculum. They also have the assurance that teaching and learning conditions will be reasonable, meaning that instructional tasks will be in line with their current abilities and informed through consultation with a variety of stakeholders, including the learners themselves. The onus on teachers is to account for educational opportunities of adequate dimensions under reasonable circumstances and in relation to the learners' capabilities.

Yet, what is not being said is also significant. Thus far, nothing has been said to suggest that the individuals themselves have to change. In this instance, I assume that the inclusive stance on curricular matters implies that as the curriculum is differentiated and adapted to the developmental level of the learner, the learner will be able to access the material, interact with it and consequently learn from this engagement and be changed through it. At the same time, the teacher supports the learning processes through using specialised teaching principles such as UDL, thereby increasing the quality of the learning experiences for all learners in the class, not just for learners with SEN. Under these circumstances, there is a strong expectation put on teachers to adapt the work and the environment for learners with SEN, and failing that, that the LSAs somehow adapt the situation even further. Aside from the teachers consulting with learners and their families with regards to the adaptations, little is said of expected change in and from the learners' side.

Feuerstein and his followers argue that learners with SEN will not necessarily benefit from all these external changes, unless we modify the cognitive structures of the learners at the same time. A key point of Feuerstein's theory, which is overlooked in curricular reforms, is that the prerequisites to learning are underdeveloped in learners with SEN, which inhibits the capacity of learners with SEN to gain directly from learning experiences. Accordingly, Kozulin *et al.* (2010) states:

> We do not believe that inclusive education would succeed if learners with developmental disabilities were just placed physically into normative classrooms. We also doubt the success in teaching them curricular subjects without simultaneously enriching their cognitive skills. A certain level of cognitive performance constitutes, in our opinion, the necessary prerequisite for successful curricular learning. At the same time the proper combination of cognitive enhancement activities and curricular studies should result in significant advancement of both cognitive and domain specific skills of special needs learners (p. 8).

A simple illustration would be to set a table with delicious delicacies for a man, yet the man cannot eat of it as his mouth is taped shut. Changing the room, the food, and the table will not help the man eat. The tape has to be removed.

Why is there such silence about the learner? I assume that as educators it is because the inclusion model itself is:

- divided, functioning on the one side of a dichotomy
- based in the social model, not on the medical model
- working with the notion of developmentally delayed, not developmentally different
- adopting the notion that learning is development
- focusing on content and informational processes, not cognitive development

Like the illustration of the man at the table, we are adjusting everything in the environment that we possibly can in the name of inclusion — the teacher, the teacher's way of teaching, the task, the resources to do the task, providing assistive technologies and allocating LSAs to learners — but still nothing is said of adjusting any states of the learner. At the same time, where we can't adjust things like the national system of measurement and its revealing test scores, we are unsure how to move forward.

What do we gain by not paying attention to the learner? We achieve a silence that we hope will prevent us from going back to a deficit model where individuals with the disability and their families are blamed and ostracized for not measuring up. We conjecture that difference does not matter in society, in an attempt to normalise and to increase levels of acceptance and tolerance for diversity. We create national curricula with performance descriptors embedded into them so that educators can use the same age-appropriate content for all learners, but "flow chart" it down the standards grid to the levels of development of learners with SEN. We advocate for social justice and equality to become a reality in our schools.

What do we achieve in actuality by not paying attention to the learners? We have shifted blame, not dealt with blame. To clarify, in the past if a learner did not respond to educational intervention, it was taken that the learner could not learn. Now if a learner does not respond, we believe that it is likely that his/her teacher cannot teach (UNESCO, 2005, p. 27). Furthermore, by not paying attention to diversity, our efforts are excluding certain learners, particularly those with emotional and behavioural challenges, from school altogether. Moreover, we lock the learner into infantilism and early childhood learning schemes, dressed up through differentiation to appear age-appropriate, without really addressing the criticism from within the social model that learners' differences are being suppressed and not addressed. We overlook that true equality can only be achieved through equity, where equity requires of us to deal with difference directly by not treating everyone the same, but by realising that different learners will need different things from school. For this reason, we have not reconciled in any meaningful way the tension between curricular standards and the current functioning and future potential of learners with SEN.

In other words, we find ourselves back at the "Dilemma of Difference", or, in this case, *indifference* to the individual's role and potential, where both acknowledging and not acknowledging the learners' needs and capacity for change lead to a confrontation with sensitive issues. Our dilemma can be expressed idiomatically as follows: "Nobody wants to hang a learner with SEN's dirty washing in public, yet turning a blind eye is as hypocritical and sweeping it under the rug is an unsatisfactory long-term solution."

2.7.1 Well-trained teachers, curricular differentiation, AND individual modification

In the final analysis, the inclusive settings are set up to design for the limitations of learners with SEN rather than to confront their limitations through design and intervention. Feuerstein, Rand and Rynders (1988) refer to a system, which tries to adapt to learners but has nothing to say about the learners themselves adapting, as the passive-acceptance paradigm. The passive-acceptance paradigm is marked by the "danger of accepting individuals as they are" (p. 128), meaning in terms of acknowledging their vulnerable cognitive functions, and doing nothing about these. Accordingly, he states that such systems give the learners a message of a comfortable existence and a good feeling, without demanding change in return. It is important to realise that Feuerstein supports inclusive initiatives such as curricular adaptation and the professional development of teachers (Feuerstein *et al.*, 1988). The point being laboured by him is that the individual learner needs to be modified and not just the curriculum or the teachers. All three entities need to come together in a meaningful and compatible combination. Accordingly, he proposes that a dynamic and interactive triad between the curriculum, the teacher, and the learners must be present to move learners beyond being recipients of support to becoming learners in their own right.

2.7.2. Supporting a wider variety of higher-order thinking processes

In Chapter 1, I stated that learners with SEN will require strong elements of support to model. More specifically, they will require support with the social skills aspect of collaborative learning as well as with the higher-order cognitive processes that are needed for problem solving. In this study, I use Feuerstein's work to define the nature of the support suitable for learners with SEN regarding the cognitive demands of modelling.

To revisit an earlier point, direct instruction benefits learners with SEN. Direct instruction includes a full explanation of the concepts and its accompanied procedures. This package of core information, concepts, and its procedures are then committed to long-term memory. Accordingly, learners are presented with problem-types for which they need to search their memory bank until they find the best-fit template to match. Thereafter, they input the content, concepts, and procedures into the problem and output the solution (Spiro & DeSchryver, 2009, p. 112). For this reason, direct instruction aligns with work in psychology that carries the suggestion that memory, rather than developmental processes or conscious thinking operations, is the most important psychological mechanism we need to look at to explain learning. By and large, memory is a mechanism that is used to explain how we manipulate, organise, store, and retrieve information, which we then use for intelligent thought or action. To understand the link between memory and intelligence, researchers began analysing the working relationship between short-term memory and long-term memory (Atkinson & Shriffin, 1968); the enhancement of the capacity of short-term memory by chunking information (Miller, 1956); and, the notion of working memory (Baddeley & Hitch, 1974).

The point I am making is that whereas the focus in direct teaching is more weighted towards recall and retrieval, problem-solving activities like modelling are generally aligned with abstract mental processing and thinking skills. The core components involved in this kind of processing are still being decided. Working memory remains a strong component of higher-order processing, and so is interest in and research into executive functions and their opaque overlap with metacognitive strategies (Schoenfeld, 1985b, 1992; McCloskey, Perkins & Van Divner, 2009, p. 1991 Kindle edition).

For the most part, direct teaching is associated with lower-order processes such as memory, perception, attention, and will, whereas modelling activates higher-order cognitive processes, taking into account that the nature of higher-order processes and their relationship to lower-order processes are still being debated. In this study, the strong demand by modelling on these cognitive processes and the identified vulnerability of these processes in learners with SEN come into the proverbial cross-hairs, when learners have to problem-solve more open-ended mathematical problems. Put differently, modelling draws on cognitive processes, which are typically underdeveloped in learners with SEN and include language and reasoning, abstract thinking, problem solving, transfer, and application of learning.

Feuerstein postulates that it is possible to change the underlying mechanisms that support higher-order thinking. He refers to these mechanisms as cognitive deficits. Besides the additional modifications specified by inclusive practice, I argue that strengthening cognitive deficits is the bridge between the modelling and the learner. For this reason, I suggest a hybrid between established learning principles formulated in curricular statements and the strengthening of cognitive deficits in the learner. Once cognitive deficits are sufficiently strengthened, it will allow dis-abled learners to become en-abled and consequently access more and more challenging curricular options over time.

The value of Feuerstein's work lies in the following:

- It makes us re-evaluate how the ability and propensity to think are acquired and maintained.
- It forces us to become more explicit in what we mean by saying that we are teaching higher-order thinking skills, and how we should go about cultivating these processes.
- It gives us insight into the reasoning processes of successful and unsuccessful thinkers.
- It explains why learners with SEN struggle with certain forms of constructivism, such as discovery learning.
- It generates learning options for learners with SEN, thereby expanding their educational alternatives beyond training and skills development.
- It offers us a way into modelling by suggesting that we use modelling as a way to develop higher-order reasoning, rather than wait until higher-order reasoning processes are stronger.

Feuerstein argues as follows: Cognitive deficits undermine thinking. As these deficits are being strengthened they will increase a child's learning potential and adaptation to inclusive practices. Cognitive deficits are strengthened through mediation. Ongoing mediation creates durable cognitive change by restructuring the brain neurology and thereby increasing fluid intelligence or the person's ability to manage new and more challenging learning experiences. I start the next section by looking at the nature of cognitive deficits, the nature of mediation — its types and techniques — and lastly I explain Feuerstein's theory of Structural Cognitive Modifiability.

2.7.3 Feuerstein's list of cognitive deficits

Feuerstein's list of cognitive deficits is pertinent to modelling with learners with SEN in so far as cognitive functions that are undeveloped, impaired, or fragile undermine learning and reasoning and consequently interfere with model-construction processes as well.

Accordingly, Feuerstein (2013, p. 17) describes cognitive deficits as proximal causes of poor intellectual performance, in contrast to distal causes, which are the original factors that led to intellectual impairment in the learner. It is important to realise that these functions are seen as precursors to higher cognitive processes, and that they are not equivalent to the higher-processes themselves. Since they are prerequisites to thinking (Sternberg, 1985, p. 221) they have an affinity with executive functions, metacognition, and mental processes alluded to in Piaget's developmental sequences without being any of these in particular (Maxcy, 1991, p. 15, 17). The number of cognitive deficits (28 in total) is relatively large and may appear confusing and overwhelming at first glance. These are described under his demarcation of input-elaboration-output mechanisms and are detailed later in the study (Section 4.6.4).

On the positive side, Feuerstein's list is seen as heuristically useful and a valuable framework for analysing thinking processes (Sternberg, 1985, p. 221; Maxcy, 1991, p. 17). Others criticize the list for being numerous and overlapping for testing situations, for being a theoretical list of attributes disconnected from one another, and disconnected from cognitive theory (Schottke, Bartram & Wiedl, 1996, p. 160).

Feuerstein has also developed a diagnostic tool called the *Learning Propensity Assessment Device.* a set of pen and paper exercises known as *Instrumental Enrichment and Instrumental Enrichment Basic*, and a *cognitive map for lesson design,* to help diagnose and remediate these cognitive deficits through an active and direct way of interacting. The way to address these cognitive deficits is through a mediated learning experience.

2.7.4 Feuerstein and mediation

In Feuerstein's view of mediation, the mediator's goal is to develop the thinking and learning processes of the learner with SEN and to raise the learner's awareness of these processes occurring. Mediation is about helping a learner organise learning experiences and stimuli by placing the teacher between the stimuli and the learner (Moonsamy, 2014). Feuerstein further stipulated that any mediation experience must contain three criteria, namely, intentionality and reciprocity, transcendence, and meaning.

- Feuerstein's view of intentionality and reciprocity corresponds to a kind of Socrates' problem solving in that the intention of the mediator is not to solve the problem for the learner, but to assist the learner with individual thinking as the solution is worked towards. Reciprocity supports intentionality in that the mediator has to work at the level where the learner is at and not try to run ahead of the learner.
- Transcendence matches the notion of generalising or transfer in education where the goal is to create an outcome that will extend beyond direct and immediate experiences (Feuerstein *et al.*, 2010, p. 13).
- The mediator has to mediate meaning by helping learners with SEN understand why the phenomenon is important and why it should be learnt. Learners also need to understand how and why their strategies were useful in this particular setting. Meaning is important to satisfy motivational and emotional forces such as finding the task personally relevant.

At the same time the mediating experience has to encourage a learner in the following parameters: feelings of competency, ability to regulate and control his/her own behaviour, to share experiences with others, to recognise individual differences; to seek goals, set goals, and achieve them; to search and work with challenge, novelty, and complexity; to look for optimistic alternatives; to feel a sense of belonging; and, to understand that one is modifiable oneself.

2.7.5 Feuerstein's work on intelligence

In contrast to the popular static views of human intelligence at the time, Feuerstein developed the theory of *structural cognitive modifiability* to express his belief in human modifiability or that people's intelligence is able to change (Green, 2014). Feuerstein *et al*. (2010) work from a higher-order structure of intelligence and consequently the change he refers to is "changes in the structure of thinking" (p. 13). He equates structural change with the development of new cognitive structures that will open up new learning experiences to the learners and that will allow the learners to interact with their world differently than what has been previously experienced. In his approach, true structural change is marked by permanence, resistance to change, flexibility and adaptability, and generalizability to other situations. It is also a behaviour that will continue on its own and will impact the overall functioning of the individual.

Research results on the effectiveness of Feuerstein’s work are mixed. Some studies (for example, Kozulin *et al*., 2010, p. 9) produced some very positive results, such as enhanced generalized cognitive modifiability in relation to improved fluid intelligence, enhanced executive functioning problems, self-regulation difficulties, visuo-motor coordination as well as social-emotional recognition skills. At the same time Gustafsson and Undheim (2009, p. 230) provide details of lists of research projects that did not yield any significant results in relation to Feuerstein's work.

The idea of extracting the principles from Feuerstein's work and applying them to mathematical learning is not new. For example, Kinard and Kozulin (2008) discuss their own work in this regard in their book *Rigorous Mathematical Thinking*.

2.7.6 Other studies using Feuerstein's work in mathematical learning

There are other studies that have used Feuerstein's work to promote mathematical thinking and reasoning. For example, Rigorous Mathematical Thinking **(**RMT) employs Feuerstein's position that underlying and underdeveloped cognitive functions will interfere with mathematical learning in children. Accordingly, Kinard and Kozulin (2008) state:

> For our discussion of Rigorous Mathematical Thinking (RMT) the issue of structural cognitive change is relevant in all three of its constituent aspects: structure, cognition and change. We claim that successful mathematical thinking is impossible without creating cognitive structures in the child's mind, first more general structures required for any type of systematic learning, and then specific structures of mathematical reasoning. Structures provide both the organization of thinking and its systematicity. Without them, children's mathematical thinking would remain a disorganized collection of pieces of information, rules and skills that does not possess the required generality or rigor. The emphasis on cognition stems from our conviction that a considerable part of learners' difficulties in mathematics stems not from the lack of specific mathematical information or procedural knowledge, but from the underdevelopment of general cognitive strategies required for any systematic learning. Mathematical knowledge itself would remain latent if not activated by the relevant cognitive processes (p. 1021 Kindle ediiton).

The difference between this study and theirs is that this study is exclusively concerned with learners with SEN and uses modelling, not RMT, as its baseline. Commonalities include that both studies are interested in using Feuerstein's cognitive functions as a bridge into mathematical learning.

2.9 CONCLUSION

I explored how curricular initiatives for learners with SEN have been shaped by discourses around democratic values, social justice, and learning theories. More recently, disability discourses have broadened their scope of change beyond access to education in terms of placement to being concerned with the quality of teaching and learning experiences to which learners with SEN have access in their respective educational environments. I agree with those who promote the views that the reconceptualization of special education starts by focusing on extending the quality of what is generally available to an increasing range of learners (Florian, 2014, p. 12). To this end, I want learners with SEN to experience modelling opportunities or challenging maths problems as part of their curriculum. Accordingly, I support both the open-gate policy in the middle school years, while simultaneously arguing that certain learners with SEN are unprepared for this confrontation.

I see Feuerstein's theory of structural cognitive modifiability as a solution, firstly, to the *Dilemma of Difference*, and, secondly, to the *Dilemma of Access to the Curriculum*. In terms of the first dilemma, Feuerstein's work proposes a dynamic triad, where the learner, the instructional task, and the teacher all have to work together and be modified in order to modify the learners' cognitive structures. When the cognitive processes of learners with SEN become stronger through joint activity, they will be able to access more of mainstream curricula independently, including modelling. In Chapter 3, I consider modelling as pedagogy and its potential for learners with SEN.

CHAPTER 3
MODELLING AS A VIABLE OPTION FOR TEACHING MATHEMATICS TO LEARNERS WITH SEN

3.1 INTRODUCTION

As explained previously, learners with SEN should ideally access common curriculum content. In the final analysis, would modelling work as an instructional approach for learners with SEN? What does it have to offer this cohort that they are not receiving through direct teaching? Is it worth their while changing over from explicit teaching to something as anomalistic as modelling by comparison? The content of this chapter suggests "yes" to these matters. All things considered, I do not want to get drawn into a debate supporting the dichotomy between direct instruction and modelling. My purpose is to focus on the argument that learners with SEN need more than instruction based on content of cognitive processes, including specific units of information, specific mathematical procedures or strategies, and specific mathematical operations. They need instruction that will develop prerequisites to thinking, and I see great potential in modelling for accomplishing this end.

This part of the study covers Task B, where Task B is as follows:

Task B: Define the critical characteristics of modelling as an instructional task and analyse it as an option for SEN classrooms

For the purpose of Task B, I discuss modelling first from a theoretical perspective, then from a practical one. Thereafter, I analyse potential benefits and limitations of modelling for learners with SEN. Last, I argue that for learners with SEN to benefit from modelling, we will have to consider a way of integrating Feuerstein's theory into our modelling practices, thereby transforming modelling into a form of cognitive education in addition to using it for mathematical learning and teaching.

3.2 AN ANALYSIS OF MODELLING AS AN OPTION FOR ALL CLASSROOMS

3.2.1 What is mathematical modelling?

There is acknowledgement of a "conceptual fuzziness" in the research community on how to appropriately define mathematical modelling and mathematical models (Lesh & Fennewald, 2010, p. 5). In this chapter, I approached the question of the nature of modelling — what modelling is — by looking at the role of the student and the role of the teacher during modelling activities. After examining literature on the subject, I came up with the following workable definition of mathematical modelling:

> Modelling involves instructional environments where students solve challenging mathematical problems that create cognitive tensions in students, which they then seek to resolve. These problems are placed in contexts that are experientially real to students and that support a variety of interpretations and solution paths. Students work in small groups in a collaborative manner and create solutions by combining their implicit knowledge drives with knowledge gained from group discussions and from their own and others' reflections. They progress through cycles of creating, implementing, and evaluating mathematical ideas. Teachers assist students in articulating their ideas, thereby making their implicit views explicit. Moreover, meaningful feedback is given to learners without overriding learners' sense-making processes or by substituting their meaning-making efforts with the teachers' own solution sets. Last, teachers help learners to formalise and generalise their understanding and align it with socially acceptable institutionalised knowledge.

3.2.2 Modelling and learning theory

A key point is that mathematical modelling is not a learning theory in its own right at this stage in its development. It is a method of teaching. What then is the theoretical framework behind modelling? Modelling is often juxtaposed against direct teaching. But does that make modelling a form of constructivism? It is important to realise that different theories bring out different aspects of modelling. To illustrate, the dynamics between teacher and learner found in modelling is a good match to Golding's (2011) description of constructivism. Golding proposes that co-operative learning groups achieve a sense of balance between polarized states. For example, they have the potential to balance states of no structure given to learning such as in radical constructivism and full teacher control found in direct instruction, between intellectual anarchy and imposed pre-determined solutions, and between relativism and dogmatism. Moreover, based on epistemic standards, there are restrictions in place as to what counts as adequate solutions and what does not. Likewise, discussions seek to draw out reasoned or reflective judgements where ideas are judged better or worse depending on the quality of reasoning supporting them, rather than presenting all opinions as equally valid or by only seeking correct answers (Golding, 2011, p. 481).

Then again, the mental work (thinking and reasoning processes) required in modelling responds to Cognitive Flexibility Theory (Spiro *et al.*, 1988, p. 1). Both orientations emphasise the use of multiple mental and pedagogical representations, the promotion of multiple connections between concepts, constructing own knowledge schemas (as opposed to the retrieval of pre-packaged schemas), the centrality of "cases of application" as a vehicle for generating functional conceptual understanding, and the need for participatory learning.

In addition, the communication prerequisites of modelling make it a good fit with persuasive pedagogy (Murphy, 2001) where learners have to present their views, interact with current knowledge, and defend their points of view accordingly.

On the other hand, modelling and system theory share a focus on adaptation and optimisation. Skyttner (2005) describes how systems theory started as a study of how biological organisms adapt to their environments. Within this theory, the idea of continual design and redesign is fundamental to optimisation. Design in the context of general systems theory is a creative process that demands an understanding of a problem, a generation of solutions, and a testing of solutions in a circular line of development.

At the same time, certain authors (Lesh & Doerr, 2003; Confrey & Maloney, 2006) argue that even though aspects of modelling may be rooted in constructivism, modelling in its current form extends beyond constructivism. Furthermore, these authors state that modelling has successfully resolved certain controversial aspects associated with constructivism, such as reconciling students' subjective knowledge components with institutionally valid constructs. I am not yet convinced that modelling is different enough to constructivism to facilitate a paradigm shift or to count as a separate theoretical orientation. It is important to remember that constructivism can assume many different forms, such as Piagetian constructivism, social constructivism, situated cognition, and distributed cognition (Section 2.5). At the same time, since constructivism is not clearly operationalized, it makes fine-grained theoretical comparisons more challenging. The way I use modelling in this study fits best with the socio-constructivist paradigm for two reasons. First, learners have to work co-operatively, and more importantly, the ideas being developed in this study are affiliated with the work of Vygotsky and Feuerstein.

3.2.3 Policy, disability discourses, and curricular situations are favouring modelling

Australia began the process of developing a new National Curriculum in 2009 (ACARA, 2013b). This is in contrast to the previous status quo where each of the five states was responsible for their own independent framework. The Australian Curriculum, Assessment and Reporting Authority (ACARA, 2013b) heads the new initiative. The National Curriculum Board (2009) in Australia has structured the mathematical curriculum to accommodate three interrelated content tiers, which are *Number and Algebra*, *Measurement and Geometry*, and *Statistics and Probability*. Proficiency levels across these tiers are measured using four strands influenced by the work of Kilpatrick, Swafford and Findell (2001), which are understanding, fluency, problem solving, and reasoning.

Equally important, modelling is an element of the ACARA and, given that learners with SEN are now included in general curricular content, it follows that learners with SEN will need to engage with modelling as part of their general curriculum studies. In addition, there are several authors who research and promote mathematical modelling across schools in Australia (Stillman, Brown, & Galbraith, 2008; English, 2010).

In the next section I describe modelling by giving consideration to the role of the student and to the role of the teacher.

3.3 THE ROLE OF THE LEARNER

Table 3.1 summarises the ideal role of the learner in a modelling environment. Each of the points in the table is discussed in more detail below.

Table 3.1 The ideal role of the learner in modelling

- Learners are active
- Learners construct conceptual frameworks
- Learners develop concepts through cyclical processes
- Learners' conceptual development is not linear nor hierarchical
- Learners make multiple connections
- Learners represent their work
- Learners symbolise
- Learners acquire knowledge through social participation
- Learners' models will be unstable
- Learners are encouraged to use their own intuitive methods and idiosyncratic concepts
- Learners articulate their thinking

Table 3.1

3.3.1 Learners are active

Learners have to play a very active role in modelling. The transmission model with its pre-packaged content delivered to a seemingly passive learner is being challenged by modellers.

> Learners do not learn from passively receiving information, but through their active participation in social practices, their reflection on these practices and through the internalisation and reorganisation of their own experiences (Swan, 2006, p. 78).

The emphasis is on the learners "doing the work" themselves. In the context of modelling, doing mathematical work includes an extensive range of activities, for example, problem posing, knowledge organisation, model building, representation, symbolisation, reflection, justification, presentation, optimisation, and generalisation of mathematical ideas.

This kind of ownership and involvement expected from the learners during modelling is found in Dewey's (1933, p. 100) notion of reflection inquiry in America, Freudenthal's (1991) notion of mathematizing in the Dutch tradition of Realistic Mathematics Education, problematizing in the problem-centred approach of South Africans (Cobb, Wood, Yackel, Nicholls, Wheatley, Trigatti, & Perlwitz, 1991), in Brosseua's (1997) work in France on the learners' responsibility of devolution of the didactical learning situation, and in the notion of problem-driven mathematics in the USA (Zawojewski, Magiera & Lesh, 2013). For the purposes of this study I will adopt the South African terminology of problem-centred mathematics.

Given the new dynamics, Gravemeijer (1994, p. 5) describes problematizing as introducing a changed didactical contract into the classroom. Essentially, the contract is in breach of the direct acquisition model or the factory-based industrial metaphor, where mathematical content is reduced to pre-packed, insulated units that are delivered to learners. Over time, learners are expected to "re-assemble" these packages into a coherent product as they progress yearly along the assembly line of mathematical teaching (Robinson, 2010). According to several authors (Kinard & Kozulin, 2008, p. 2313 Kindle edition; Dai, 2010), a new type of didactical contract is necessary to further advocate for the standards of mathematical education to be expressed as products rather than processes, for thinking processes in mathematical learning to receive proper attention, and for classroom mathematics that nurture learners' interpretive, evaluative, and reflective mathematical reasoning.

The outcome desired by the problem-centred approach is understanding (Cobb *et al.*, 1991; Gravemeijer, 1994; Kinard & Kozulin, 2008; Zawojeski *et al.*, 2013). By rendering understanding as a key and final outcome, this approach questions Bloom's (1956) taxonomy and the related work of Anderson and Krathwohol (2001). Anderson and Krathwohol translated Bloom's nouns into verbs, leaving us with thinking actions. The thinking actions are remembering, understanding, applying, analysing, evaluating, and creating and, as in Bloom's taxonomy, these are sequential and hierarchically organised. In contrast to Bloom and his followers' work, the problem-centred approach posits that the process of understanding is the product of thinking and not a type of thinking. Simply put, understanding is seen as one of the primary goals and not as a building block (adapted from Ritchart, Church and Morrison, 2011, p. 6-7) of thinking.

As can be seen, the problem-centred approach challenges more traditional mathematical education paradigms by suggesting alternative practices (problematizing), alternative products (understanding), and also alternative types of thinking (theoretical cognition). Similar to Davydov, the problem-centred approach argues that the type of thinking that is being produced in mathematics education must be changed. Davydov (1990) comments:

> New methods of designing instructional subjects should project the formation of a higher level in the learners' thoughts than the level toward which the traditional teaching system is oriented. The content and methods of traditional teaching are oriented primarily towards the learners' cultivation of fundamentals and rules of empirical thinking — this is a highly important but at present not very effective form of rational cognition. (p. 3)

3.3.2 Learners construct conceptual frameworks

There is support for the idea that a mathematical model is a human conceptual schema (Davydov, 1990, p. 122; Lesh & Doerr, 2003; Tang, 2011).

Trying to understand how mathematical learning develops into a conceptual schema or cognitive object is a topic that has been actively pursued by cognitive scientists since the first cognitive revolution and its historical break from behaviourism (see next Chapter). Moreover, several modern authors from within the field of mathematics research have built on the legacy of Piaget and Vygotsky to theorise potential avenues of how cognition may morph into or generate mathematical concepts or mathematical cognitive objects. Examples include Dubinsky's (1991) work on APOS (Action/Process/Objectification/Schema), Tall and Gray's (1994) notion of a procept, Sfard's (1991) theory of reification (to reify carries the idea to materialise, to commodify, or to convert mentally to a "thing"), and Dörfler's (2000) analysis of protocols of action.

Rouse and Morris (1986) remind us that the "acceptance of the logical necessity of mental models does not eliminate conceptual and practical difficulties; it simply raises a whole new set of finer-grained issues" (p.1). There are still too many questions when it comes to understanding conceptual structures. What are concepts really? Do we need to think of them in terms of objects, categories, prototypes, neural activation areas, relational networks, or in other ways? What are the primary and secondary mechanisms that drive their formation? What are the differences between conceptual knowledge and concept transcending knowledge, if any?

Proponents of modelling suppose that conceptual change is theory-like in character and facilitated through the process of constructing and reorganizing personal conceptual models (Jonassen, Strobel & Gottdenker., 2005). Simply put, conceptual change is rooted in model building and model reasoning (Jonassen *et al*., 2005).

Conceptual development in modelling has more in common with conceptual change theories than conceptual enrichment theories.

From a conceptual enrichment perspective (Spelke, 1994), conceptual development means knowledge incrementation. Meaningful learning is an expansion of content through addition to the core principles. The underlying mental schema does not change in form but only increases in content. Conceptual change is really conceptual growth. Since, in this model, conceptual change results from the accretion of information, mathematical learning is the adding of standard mathematical content such as rules, procedures, definitions, axioms, and algorithms, plus inference rules in a systematic and hierarchical manner to expand on principles previously acquired. In this approach, conceptual development is quantitative as it depends on having increasingly larger quantities of mathematical information and principles to support the already existing ontological type.

On the other side of the coin (Carey, 1999; Vosnaidou & Vamvakoussi, 2006), it is proposed that conceptual change that requires more scientific theories (such as school learning) is a qualitative change and not a quantitative one. A distinction is made between a weak and a strong conceptual change (DiSessa, 1998). A weak conceptual change is when the relations between concepts change and the concepts became connected or reconnected in a new and more meaningful manner. A strong conceptual change suggests that the actual core of the components themselves has been altered (DiSessa, 1998). To clarify, in a strong change setup, it is not the amount of components or the relationships between the components that have changed, but the very components that are at the core of the concept themselves that are different. Simply put, learners must build new ideas in the context of old ones, hence the emphasis on "change" rather than on simple accumulation. New principles emerge that are incommensurable with the old and that creates a new ontological type by overriding previous core principles. There is no co-existence of old and new conceptions. There is only a replacement of what previously existed. It is revolutionary in nature, in that it requires radical restructuring and re-organising of schematic information to reach a different level of comprehension — a paradigm shift. In this view, simply adding information to strengthen and enlarge existing structures is not enough. Schoenfeld (2004) comments:

> The naïve view is that mathematical competence is directly related to what one "knows" (facts, procedures, and conceptual understandings) — and that knowledge accumulates with study and practice. This is hard to argue with as far as it goes. It is, however, dramatically incomplete. (p. 11).

Questions are being asked about whether theory modification may not be a more suitable alternative to theory replacement, especially in the mathematics and science realms. Proponents of theory modification reject the view that learners' existing concepts and understandings tend to be treated as something that need to be overcome or abandoned in order to gain a correct scientific account of the concept in question. In line with Vygotskian thought (1996) on working with both everyday concepts and scientific concepts in the Zone of Proximal Development, they propose instead that both set of concepts, scientific and everyday knowledge, should be discussed and learners should be taught how to differentiate between them..

Model-based reasoning and Neo-Piagetians have in common the view that learning starts from existing representational structures, meaning that they work with the already existing knowledge structures of the learner. Moreover, conceptual change theorists and modellers both argue that eventually one ends up with "something new" that cannot feed back into the original structure. Modelling also overlaps with the theory modification group in that both hold that the partially correct preconceptions of learners can be modified and be built upon. The notion is not to "replace" learners' prior knowledge but to gradually transform it through encouraging modification of learners' existing models. Essentially, model building is a cyclical iterative process with multiple opportunities for adjusting and refining the model, which will bring about conceptual understanding and conceptual change.

3.3.3 Learners develop concepts through cyclical processes

Conceptual development and cognitive tools start germinating as learners work through multiple cycles of revision, testing, and expansion of the original model (Lesh & Doerr, 2003). Conceptual change is seen as the production of a sequence of intermediate conceptual models that become progressively more expert-like (Clement, 2008). Learning thus occurs through progressive refinement and (re) organisations. Within each cycle, more sophisticated and explicit knowledge of constraints relating to general principles of the science and mathematical equations will play a role in (re)-constructing and manipulating these models.

The rendering of the processes are generally depicted using flow type diagrams or a verbal listing of traits with various degrees of detail.

In Blomhøj and Jensen's (2003, p. 125) work, six sub-processes are identified:

- Formulation of a task (more or less explicit) that guides you to identify the characteristics of the perceived reality that is to be modelled.
- Selection of the relevant objects, relations, et cetera, from the resulting domain of inquiry, and ideation of these in order to allow a mathematical representation.
- Translation of these objects and relations from their initial mode of appearance to mathematics.
- Use of mathematical methods to achieve mathematical results and conclusions.
- Interpretation of these as results and conclusions regarding the initiating domain of inquiry.
- Evaluation of the validity of the model by comparison with observed or predicted data or with theoretically based knowledge.

Likewise, Blum's (2000) (cited in Mousoulides, Sriraman & Christou, 2008, p. 3) suggestion of the modelling cycle is as follows:

- describing the problem,
- manipulating the problem and building a model,

- connecting the mathematical model with the real problem,
- predicting the behaviour of the real problem and verifying the solution in the context of the real problem,
- communicating the model and its results,
- and, controlling the process through self-adjustment.

The model that will be used in this study is that of Sekerák (2010, p. 106). Sekerák's three phases are:

1. Identification of model situation starting points,

2. Construction of a mathematical model,

3. Verification of the built model.

According to Sekerák (2010, p. 106), the first phase relates to identify the starting points and their relations. The first phase is essentially an information-gathering phase where the participants have to decide which information to include and which information to omit. The second phase is the construction of the mathematical model, where information from the first phase is translated into mathematical language. This process is called "mathematising" and the results of or products from this phase are some form of mathematical representation whether pictorial, linguistic, or symbolic in nature. He states that whereas this is probably the most important one in the mathematical process, it is also the "hardest" or most difficult one for the learners. The last phase is the verification of the model. It is in this phase where the suitability of the model in terms of its correspondence to real life, is ascertained. In his framework Sekerák refers to the last phase as de-mathematising, that is, checking that the mathematical representation adequately presents the real situation.

Table 3.2 provides a comparison of Blomhøj and Jensen's (2003), Blum's (2000), and Sekerák's (2010) descriptions of the phases of modelling for learners.

Table 3.2 A comparison of three authors' cycles of modelling

<table>
<tr><th>Blomhøj and Jensen (2003)</th><th>Blum (2000)</th><th>Sekerák (2010)</th></tr>
<tr><td>Formulation of a task</td><td>Describing the problem</td><td rowspan="2">Identification of model situation starting points</td></tr>
<tr><td>Selection of the relevant objects and relations</td><td rowspan="3">Manipulating the problem and building a model</td></tr>
<tr><td>Translation of these objects and relations from their initial mode of appearance to mathematics</td><td rowspan="2">Construction of a mathematical model</td></tr>
<tr><td>Use of mathematical methods to achieve mathematical results and conclusions</td></tr>
<tr><td>Interpretation of these as results and conclusions regarding the initiating domain of inquiry</td><td>Connecting the mathematical model with the real problem,</td><td rowspan="3">Verification of the built model.</td></tr>
<tr><td>Evaluation of the validity of the model by comparison with observed or predicted data or with theoretically based knowledge</td><td>Predicting the behaviour of the real problem and verifying the solution in the context of the real problem</td></tr>
<tr><td></td><td>Communicating the model and its results</td></tr>
<tr><td></td><td>Controlling the process through self-adjustment</td><td></td></tr>
</table>

Table 3.2

Borromeo-Ferri (2006) completed an analysis on the variety of empirical modelling cycles depicted by authors. She pointed out that these cycles are similar in that the descriptions of the phases are normative and are seen as an ideal way of modelling. The differences in the cycles could be attributed to several factors including, but not limited to, various directions and approaches of how modelling is understood theoretically by authors and within different countries, whether complex or non-complex tasks are being used, and certain tendencies to see specific phases as mixed or as separate.

Another pertinent question that emerged from Borromeo-Ferri's analysis is whether we have a need for researchers to embrace one model and for learners to work according to their own model. Given that learners may not view modelling in the same way as adults, there might have to be a distinction between how learners think and what model may prove useful to them as opposed to how researchers think and what models may be effective in their work.

3.3.4 Learners' conceptual development is neither linear nor hierarchical

The cyclical nature of modelling suggests that conceptual frameworks do not develop along predetermined lines. Whereas Bloom's (1956) influential taxonomy supposes a sequential and hierarchical thought development trajectory with predetermined outcomes ranging from lower-order to higher-order levels of thinking, modelling is more in line with views that see thinking as a dynamic interplay instead — a backwards and forwards motion between several elements.

Bloom (1956) suggests that knowledge precedes comprehension, which precedes application, and so on. However, we can all find examples from our own lives where this is not the case, as Ritchhart, Church and Morrison (2011) discuss:

> A young child painting is working in application mode. Suddenly a surprise colour appears on the paper and she analyzes what just happened. What if she does it again, but in a different place? She tries and evaluates the results as unpleasing. Continuing this back and forth of experimentation and reflection, she finishes her work of art. When her dad picks her up from school she tells him about the new knowledge of painting she gained that day. In this way, there is a constant back and forth between ways of thinking that interact in a very dynamic way to produce learning. (p. 6)

Learners do not only have to work through multiple cycles, they also need to work through multiple layers of understanding. Van den Heuwel-Panhuizen (2000, p. 5) refers to the multi-layered aspect of modelling as the principle of levelling and suggests that it includes working through shortcuts, schematisations, representations, bridging principles, and so on to move from an informal to more formal model of mathematical knowledge.

3.3.5 Learners make multiple connections

During modelling tasks, learners make multiple connections and construct complex pathways. To illustrate this, Lesh and Doerr (2000, p. 363-364, 2003, p. 10) discuss modelling in terms of building a system. These authors depict a model as a system consisting of elements, relationships among elements, operations to describe how the elements interact, and patterns or rules that apply to the relationships and operations. Moreover, they state that modelling involves the interaction of three types of systems. For example, learners have to connect an external system that relates to natural or human artefacts (economic systems, mechanical systems, et cetera) with their own internal conceptual systems, and then connect both these systems in a representational system. These systems and/or system components are overlapping, connecting to each other and drawing from one another during mathematical learning. Simply put, understanding learning necessitates an analysis of the interactions and relationships being setup amongst the various parts within the system and amongst the system under construction and other schemas (diSessa, 1998). Van Galen *et al.* (2008, p. 17) remind us that the networks of relation are not only conceptual in nature. At some point, learners have to connect to the procedural aspects, which is also a transition implied in Lesh and Doerr's rules and operations. The procedural transition is not an easy transition for some learners and they may need several additional opportunities to develop procedure knowledge (Van Galen *et al*., 2008, p. 17).

3.3.6 Learners represent their work

As was noted above, conceptual systems need representational tools. These tools help to support reasoning and act as a medium of communicating and sharing information. A fundamental presupposition of cognitive science is that humans think about real and imaginary worlds though internal representations. One role of representation is helping learners express externally what they are "seeing" internally. Representational tools are thus necessary to describe external systems and to express internal ones. Lesh and Doerr (2000) explain that "the purpose of representations in this development is not only for learners to communicate with one another; it is also for learners to communicate with themselves and to externalise their own ways of thinking so they can be examined and improved" (p. 368).

To facilitate communication, many kinds of representations are used in modelling. These may include, but are not limited to, linguistic modes in the form of verbal or written communications, visual communications including gestures, pictures, diagrams, concrete manipulatives, or computer simulations, as well as conventional notations expressed, for example, in mathematical equations. Different representational systems will emphasise (and de-emphasise) different aspects of the concept. To clarify, Dai (2010, p. 660 Kindle edition) states that in an instructional content with curricular activity there can be three levels of representation:

- representation of subject matter as part of the curricular content in its purposes, structure, and functionality;
- representation of the informational content as part of a larger body of domain knowledge and its epistemic value and practical utilities;
- and, representation of content being learnt as a cultural way of knowing and part of social practice that produced this body of knowledge (i.e. recognising it as a particular kind of socially sanctioned meaning making or problem solving).

3.3.6.1 Learners symbolise

Traditionally, symbolising was seen as a unidirectional process. It generally took the form of attaching a semiotic placeholder to an already extant object. Yet, within the modelling framework assumptions regarding the co-emergence of meaning and symbolisation are introduced (Sfard, 2000; van Oerts, 2000). The relationship between learning and symbolising now has a reflexive nature in so far as symbols and their meanings are continually revisited and revised as learners re-organise their own thinking and engage in communication with others in the classroom.

Proponents of mathematical modelling generally agree that learners should be engaged in activities, reflections, and discussions that show how a symbol is used in action, rather than handing learners ready-made symbols and assuming that they can decode them in a similar manner to an expert. But, there are differences of opinion as to whether learners should be initially encouraged to invent their own symbolism as they develop a model or whether the modelling activities should be more geared towards exploring already existing mathematical notation. Authors such as Bransford *et al.* (2000) argue that learners need to be initiating into already existing symbols and their meanings, whereas others such as Nemirovsky and Monk (2000) state that it is important that learners are given opportunity to invent their own symbol systems. Those who side with the latter support the general claim that it is unrealistic to expect that learners will create representations in line with the standardized conventions that have evolved in the course of mathematical history.

3.3.7 Learners acquire knowledge through social participation

Engagement in modelling also affects the level and type of social participation. Although there are elements of Sfard's (1998) acquisition metaphor and her participation metaphor in modelling, modelling tends to fit better with a third metaphor, which is the knowledge creation metaphor of learning suggested by Paavola and Hakkarainen (2005, p. 539). These authors' argument is that knowledge creation must be seen as more than the individual building his own knowledge structures with the aim of creating a logical system of organised content with rules that allow transfer to new situations. It is also more than just being part of a culture and learning how to act in a socially sanctioned manner. Knowledge creation entails a unique quality of collaborative activity that leads to shared objects and artefacts, both intellectual and physical.

In line with the knowledge-creation metaphor, the modelling approach provides a rich and balanced blend in its consideration of the individual, the group, the subject domain, and the cultural context. It covers the concern for the individual in that the individual has to mathematise, explore, justify, and own the knowledge. There is a concern for the group, the individual has to work within a group and negotiate arguments between groups. At the same time, there is an acknowledgement of the dynamics between individuals and groups — the group affects the individual and the individual in turn changes the dynamics of the group. And lastly, there is concern for the subject matter — the learning of mathematical principles and content.

A key point is that modelling involves collaborative learning. Collaborative learning is about a group of learners working together on a task. As an illustration, Damon and Phelps (1989, p. 9) distinguish three types of collaborative learning experiences, namely, peer tutoring, co-operative learning, and collaborative learning. These authors make the distinctions by contrasting one another along dimensions of equality and mutuality of engagement. In their framework, peer tutoring tends to foster dialogues that are relatively low on equality and varied in mutuality; cooperative learning foster ones that are relatively high in equality and low to moderate in mutuality; and peer collaboration fosters ones that are high in both. On the positive side, Gillies and Khans (2008) describe that some of the core intentions of collaborative learning are to provide learners with opportunities to communicate with one another, share information, and to develop new understandings and perspectives through this kind of reciprocity. In reality, the nature and dynamics of collaborative learning can result in unintended consequences. For example, we know from research that learning in collaborative setups is affected by perceptions of power amongst group members. Webb (2013, p. 22) provides a list of incidences that will undermine group performance. These include learners failing to share elaborate explanations, not asking for help when needed, disengaging from the group, suppressing others' participation, engaging in too much conflict or avoiding it all together, not co-ordinating their communication, or engaging in negative social-emotional behaviour that impedes group functioning.

All things considered, Black-Hawkins (2014, p. 392) reminds teachers who use collaborative learning techniques to hold on to the mindset that collaboration is a resource for learning, dependent on the range, experiences, and expertise among class members, and not simply a problem to be overcome. She also adds that collaborative learning necessitates a consideration of the emotions of learners evoked through participatory processes. She explains that evaluating the emotions of learners with SEN is not done sentimentally, but in a systematic way during the modelling process by taking heed of expressions that are negative like fear, humiliation, anger, intolerance, and failure and of more positive ones like feelings of confidence, joy, kindness, resilience, and respect. Likewise, Grosser (2014) argues that cooperative learning argues that the focus of cooperative learning is on social interaction and not necessarily on explicit cognitive processes. It creates opportunities for actively mediating cognitive skills and metacognitive awareness

3.3.8 Learners' models will be unstable

Learners have to use their own informal knowledge structures, such as beliefs, imaginations, hunches, passionate commitments, and personal experiences. These types of knowledge express knowledge types such as Polanyi's (1958) notion of personal knowledge, as opposed to knowledge contained in declarative sentences and logical propositions. Put differently, learners will need to use their common sense to connect with the mathematics and to generate solutions (Gravemeijer, 1994, p. 2-3) and in doing so, the mathematics become part of their common sense.

Not only do learners need to generate their own solutions, they also need to organise their own knowledge. For a long time, a prominent view in mathematics education was that curricula developers and teachers should devise materials that represent mathematical meanings and concepts to learners in a readily apprehensible form. In other words, teachers prepare content and worksheets or use textbooks that contain all the information the learners have to study. The structure and content of learning are thus largely "other-organised". The underlying principles are that learners need to adapt their internal mental representations to exactly mirror the ones presented to them externally. Learners are told at the outset "what" to think, "how" to think and "when" to think it. Mathematicians such as Freudenthal (in Gravemeijer & Terwel, 2000) saw "other-organised" material as an upside down approach to mathematical education. He felt that the threat of such an approach was starting with the product or result of the mathematical process and, in doing so, bypassing the mathematical activity that delivered the result in the first place. It was the organizing activity itself that was central to Freudenthal's (1971) conception of how learners acquire knowledge of mathematics:

> [Mathematics as a human activity] is an activity of solving problems, of looking for problems, but it is also an activity of organizing a subject matter. This can be a matter from reality which has to be organized according to mathematical patterns if problems from reality have to be solved. It can also be a mathematical matter, new or old results, of your own or others, which have to be organized according to new ideas, to be better understood, in a broader context, or by an axiomatic approach. (p. 413)

The notion that learners need to draw on their own tacit knowledge, intuition, sense-making, knowledge organisation, and refinement skills affects the stability of the schema under development. For this reason, whereas the Neo-Piagetians presuppose a form of stability within the schema, modelling suggests a far more unstable setup — one that appears situated, piecemeal, multidimensional, and volatile (Lesh & Doerr, 1998). The schemas are unstable because unlike traditional mathematics, learners are not given prepackaged schemas, but they are called on to develop their own schemas in situ through implicit knowledge drives. However, as explained later in this section, the aim is to refine the models over time into more stable and robust units that reflect mathematical reasoning. The primary idea here is that the work of constructing the information, and its derivatives of understanding and meaning, must be done by the learner and not be bypassed by giving the outcome to learners in final form.

3.3.9 Learners are encouraged to use their own intuitive methods and idiosyncratic concepts

As was noted above, learners are encouraged to actualise states such as the implicit, the instinctual, the imaginative, and the intuitive. In light of these factors, there is a growing position that mathematical modelling is not simply an aid to logical reasoning but constitutes a distinct form of reasoning.

Since learners are encouraged to use their own intuitive methods and strategies, mental modelling is considered by some as a form of informal reasoning. In its informal role, modelling is positioned as an alternative to formal logic (Clement, 2008) and a subsequent response to the gaps in human thinking that is over-reliant on rules of deductive reasoning. English (1997) describes the type of thinking found in modelling as "a move away from the traditional notion of reasoning as abstract and disembodied" to the contemporary view of reasoning as "embodied" and imaginative" (p. vii) .

We do not yet know enough about the cognitive processes involved in modelling. Research suggests that modellers tend to draw heavily on analogical reasoning powers. Effective modelling also seems to rely on spatial representations rather than visual imagery (Knauff, 2006). Correspondingly, Johnson-Laird (2001) focuses on modelling as the function of reasoning with possibilities. He asserts that each model represents one possibility. Moreover, initially models tend to only focus on what are perceived as truth states, meaning that in modelling reasoning does not spontaneously consider alternative truth states or falsities. Consequently, models tend to be parsimonious representations. Considering Johnson-Laird's (2001) tenets about reasoning with models helps with the justification of why mathematical modelling benefits from a socially-situated learning approach. Different groups generating different models and discussing and evaluating these with one another will challenge learners to reconsider the range of possibilities they are considering as well as their truth claims. Following the discussions, learners then have to find ways to reduce multiple models into a single model to make their thinking more effective.

In the Davydov (1990) framework, a model is presented as a form of scientific-theoretical cognition:

> Models are a form of scientific abstraction of a particular kind, in which the essential relationships of an object which are delineated are reinforced in visually perceptible and represented connections and relationships of materials or symbolic elements. This is a distinctive unity of the individual and the general, in which the features of a general, essential nature comes into the foreground. (p.122)

To explain, theoretical learning presupposes that an object or issue is analysed in terms of its essential features from within its material context and purpose. In other words, learners need to be familiar with both its origins and its necessity. Learners also need to uncover the content and structure of the object or phenomenon. The analysis yields a model which can be object-like, graphic, and/or symbolic. The model is then manipulated through object-like actions to reflect the essential relationships/connections of the object and to determine the properties and the boundaries of the object. Gradually, learners shift from an object-like state of action to working exclusively on the mental plane (Davydov, 1990, p. 173-174; Kinard & Kozulin, 2008, p. 858). How is a model theoretical instead of empirical? Schmittau and Morris (2004) give detailed examples of what a theoretical orientation (as opposed to an empirical approach) looks like at elementary school level. In the theoretical orientation, learners have to work extensively with relationships between quantities — how to represent them in algebraic structures, compare them, act on them. The arithmetic of the real numbers follows as a concrete application of these algebraic generalizations. In contrast, traditional methods work on numbers, and actions on numbers, and much later work their way into generalized algebraic structures. Thus, while learners in the US have pre-algebraic experiences that are numerical, Russian learners studying Davydov's curriculum have pre-numerical experiences that are algebraic.

Some of the latest psychological work on intuition is expressed by Daniel Kahneman (2011). He refers to two modes of thinking that exist in human cognition. The first is intuition or System 1 and the second is reasoning or System 2. Intuition is considered to be a system that is fast and automatic, whereas reasoning is slow, controlled, and flexible in nature. By comparison, System 1 is associative while System 2 is rule-governed. System 1 functions using associative coherence, which is not necessarily rational. Moreover, the associative network has bias as it resorts to frequency and it chooses something to fit the context of the current thinking — even if it is surprising. System 1 will find a way to fit it into the context, it anticipates the future, and it prepares for the future, but it also interprets the present in light of the past. In contrast, System 2 is deliberate and actions are related to control, to rule-governed behaviour, attention, intention, sequential development, and deliberate effort. Put differently, System 2 is the spokesperson for System 1. It is involved in the control of behaviour and the control of thought. It tries to explain or rationalise System 1.

To illustrate these concepts, Kahneman (2011) uses the example of a picture of a woman with an angry face and a calculation of 17 x 24 = 408. He argues that with the picture the response of the audience will be immediate and involuntary in that they will spontaneously perceive the anger state. However, with the calculation they will need to resort to a slower method of working out the sum in order to verify the answer. Moreover, they can choose whether or not they want to do the calculation. His argument is that intuition is a state of "jumping to conclusions" that may or may not be accurate. One of the purposes of System 2 is to monitor the accuracy of System 1 by checking the answer/response. The monitoring, however, is rather lackadaisical.

If the response from System 1 generally looks and feels right, then it is accepted by System 2. If something interferes with the ability of System 2 to monitor System 1, then performance changes. For example, when people were asked to remember a 7 digit number while doing something else, the performance of System 2 diminished. The interplay between System 1 and System 2 during the different phases of modelling needs to be explored further.

3.3.10 Learners articulate their thinking

In modelling, learners are encouraged to articulate their interpretations. This may involve inner speech as well as exteriorised speech (Swan, 2006, p. 79). However, a strong focus in modelling is rationality as partly a group activity. Small peer groups act as resources to develop, organise, and articulate their ideas in the best way. The vantage points of these various small groups are submitted to forms of reasoned agreement and disagreement. It is about taking solutions to their end through narrative explanation until it is clear that certain solutions are better (and worse) than others through a thorough analysis of their strengths and weaknesses. Groups are afforded both the opportunity to defend/justify their own intellectual solutions and to switch to other ideas that may be better than their own.

3.4 THE ROLE OF THE TEACHER

Table 3.3 summarises the ideal role of the teacher in a modelling environment. Each of the points in the table is discussed in more depth below.

Table 3.3 The ideal role of the teacher in modelling

- Teacher selects suitable problems
    - Problems that can be problematized
    - Realistic
    - Rich Tasks
- Teacher lets the learners experience cognitive conflict
- Teacher mediates between learners and between learners and content
- Teacher helps the learners formalise their knowledge
- Teacher helps learners generalise
- Teacher believes that learners learn through modelling

Table 3.3

3.4.1 The teacher has to select suitable problems

The teacher's selection of problems has to match certain criteria. For example, learners must be able to problematize the content. To problematize, the content has to generate cognitive obstacles. It should also be based in contexts that are experientially real to the learners. Moreover, the situation should be age-appropriate, developmentally-aligned, and culturally sensitive.

3.4.1.1 Problems that can be problematized

Problematizing in modelling and problem-solving in traditional mathematics are not the same thing (Hiebert *et al*., 1996, p. 12-21).

To clarify, Zawojeski *et al.* (2013, p. 238-240) explains that typically in problem-solving activities during mathematics lessons, the problem has already been defined before it is presented to the learner. The task of the learner is to find the correct procedure, plug the correct variables into the procedure, and compute a correct answer. The problem definition and the goals are both static, and the solution pathway is generally uni-directional. Put differently, learners have to work in a single interpretation cycle from a set of givens to a particular solution. When learners get stuck, they are encouraged to "navigate through the roadblock" successfully by using problem-solving heuristics that are typically variants of Polya-like operations.

In contrast, problematizing as applied to mathematical modelling is about finding ways to mathematically interpret meaningful situations. The goals and endpoints are neither given nor static. They are dynamic in nature and it is consequently required that learners problem-pose as well as problem-solve. Learners are encouraged to find ways to adapt, modify, refine, and represent the ideas that they do have, rather than to try and find ways to be more effective when they are stuck. As modelling involves multiple cycles of thinking and multiple solution paths, learners also have to reflect on the strengths and weakness of alternative representations. In the final analysis, modelling is more akin to the outcome of becoming a problem-solver rather than learners gaining familiarity and skill in solving a particular type of problem.

3.4.1.2 "Realistic" Principle

Promoters of mathematical modelling like Kaiser and Schwarz (2006) make it very clear that following in the footsteps of the "realistic" principle does not mean that mathematics teaching should be reduced to just reality-based examples but that these should play a central role in education.

Rather, "expanding reality" (Freudenthal, 1991, p. 17), as a derivation of the Dutch *realizen*, embraces aspects of the imagination (Van den Heuwel-Panhuizen, 2003) and thus any problem-situation that learners can simulate or imagine and thereafter own. The intent of "reality" as used by modellers is therefore, according to Freudenthal (1991), not restricted to the "mere experience of sensual impressions" (p.16). Van den Heuwel-Panhuizen (2003) explains that it "does not mean that the connection to real life is not important. It only implies that the contexts are not necessarily restricted to real-world situations. The fantasy world of fairy tales and even the formal world of mathematics can be very suitable contexts for problems, as long as they are 'real' in the learners' minds" (p. 10). Busse (2011) suggests using the "contextualised idea" (p. 42) for the notion of mental representations from real-life situations offered by mathematical tasks.

An expansion of the idea of realism is the move from physical realism to cognitive realism in authentic learning in Australia (Herrington, Reeves & Oliver, 2010, p. 89-90). Advocates of cognitive realism shift the focus from how much physical reality is mirrored in the tasks to how real the actual problem-solving processes are that are being invoked by the task. Simply put, the task has to promote realistic problem-solving processes irrespective of whether the task is real, realistic, simulated, or virtual.

Their alignment on issues around realism does not mean that authentic learning and modelling are the same thing. Authentic reality is a broader term than modelling. It is open to a range of problem-solving heuristics and may incorporate a variety of problem-solving tasks (routine, applied, multi-modal, non-routine, open, closed, and so on). In this context, modelling itself could be a sub-process within authentic learning if need be. In contrast to the openness of authentic reality to a larger collection of problem-solving routes and tactics, modelling is more bound by a discrete set of design principles that focus on model building in particular

3.4.1.3 Rich Tasks

Lovitt and Clarke (2011, p. 1, 2) define the term "rich" in relation to mathematical tasks. According to their criteria, a rich task has some of the following features:

- It draws on a range of important mathematical contents
- It is engaging for the learners
- It caters for a range of levels of understanding, so all learners are able to make a start
- It can be successfully undertaken using a range of methods or approaches
- It provides a measure of choice or openness, leading to a sense of learner ownership
- It involves learners actively in their own learning
- It shows the way in which mathematics can help to make sense of the world

- It makes appropriate and effective use of technology
- It allows learners to show connections they are able to make between the concepts they have learned
- It draws the attention of learners to important aspects of mathematical activity
- It helps teachers to decide what specific help learners may require in the relevant content areas, or ways in which learners might be extended

Lovitt and Clarke (2011, p. 2) further argue that the lessons are balanced when the above features work together in harmony, are mutually self-supportive, and not over- or underweight in any aspects.

3.4.2 The teacher needs to let the learners experience cognitive conflicts

During modelling, it is important that the initial state of problematizing where the learners are feeling unsettled is not revoked but is reworked by the learners to reach a state of settlement. The traits required by the initial state may appear negative in form and may be indicative of confusion, incoherence, and fragmentation on the learners' sides. They should not, however, be circumvented but should be considered traits that are necessary to activate and actualise the search for resolutions (Dewey, 1933/1991, p. 100). While learners engage in the acts of resolving their cognitive conflicts, teachers need to watch and listen very carefully. In respect to watching the learners, teachers need to become keen observers and investigators of learners' actual learning processes. More specifically, teachers need to pay attention to the progressive schematisations, not only of content, but, more importantly, of the psychological processes of learners as they reconstruct mathematical knowledge from their own thinking processes and insights. Understanding the psychological progression of learners will enable teachers to differentiate appropriately within a local context and design a learning theory for that context (Freudenthal, 1988, p. 134, 137). Simply put, by observing how learners learn, teachers will learn how to teach and consequently develop a local theory of instruction.

With respect to listening to the learners, Yackel, Stephan, Rasmussen and Underwood (2003, p. 103) add the notion of generative listening to the teachers' roles. Generative listening is more than actively listening respectfully for facts (knowledge) and for feelings (empathy). It is an inventive and creative act of listening, which according to Yackel *et al.* could serve as a conceptual tool to generate resources and connection points that will help learners problematize more effectively.

3.4.3 The teacher has to mediate between learners and between learners and content

As was noted above, the role of the teacher is to select suitable problems and then to allow learners the space to own these problems. For the sake of completeness, it is reiterated here that owning the problem in a problem-centred approach is a direct reference to the need of the learners to bridge from their own insights into mathematical insights. Teachers can help learners "bridge" through the sequence of mathematical activities they plan. Realistic mathematics proponents adopt Freudenthal's (1991) concept of guided re-invention to help learners reinvent mathematical understanding through a series of well thought out sequences, preferably based on the historical progression of mathematical ideas in the field. Streefland (1993) refers to it as "the science of structuring" (p. 109), where educators have to reflect on how they have structured the activities. An associated concept in design is the hypothetical learning trajectory (Simon, 1995, p. 135) and its intended aim of planning tasks that connect learners' current thinking activity with possible future thinking activity.

Practically, the teacher could also assist learners in their thinking "by playing the devil's advocate", for example, encouraging the articulation of intuitive viewpoints, by challenging with alternative perspectives, and by providing meaningful feedback to their ideas (Swan, 2006, p. 79). Freudenthal (1991) cautions that a considerable amount of patience is required by the teachers, not so much in respect to patience with the children, but in respect to patience with themselves as teachers to resist the temptation of simply providing the learner with the given rule or algorithm. In other words, the teacher has to display considerable sensitivity and take care not to impose their own solution templates onto the learners, but to give the learners opportunity to develop their very own thinking patterns.

The function of developing a mathematical attitude is also implicit in bridging. A mathematical attitude is fostered by teachers making sure that learners become increasingly familiar with the activities of problematizing, with the language of mathematics, the structure of mathematics, in gauging the precision of mathematical outcomes, and with working with alternative perspectives (Freudenthal, 1988, p. 143).

3.4.4 The teacher helps learners formalise their knowledge

In modelling, teachers maintain a balancing act between learning and teaching where learners have the freedom to construct their knowledge, but teachers have the responsibility of guiding their constructions into mathematical purposes. Although learners have opportunities to control their learning trajectories, teachers are required to intervene to help learners move their thinking into acceptable mathematical knowledge. It is also important for the teacher to foster institutionalised or socially agreed conventions of the concepts (Swan, 2006, p. 79).

For example, when one considers that a model is a system for describing (or explaining or designing) another system(s) for some clearly specified purpose (Lesh & Fennewald, 2010, p. 7), and at the same time is separate from the world but co-constructed with it (Doerr & Pratt, 2008), it is tempting to imagine two models — a real-world one and a mathematical model. Authors such as Kaiser and Schwarz (2006), are quick to alert one that the conjecturing of two models is not necessarily the desired outcome. Rather, they encourage their readers to think of the core of modelling as the actual transition from a life situation into a mathematical scenario. Likewise, Gravemeijer (1994) describes how a learner's model should move from being grounded in a specific setting, typically an out-of-school setting. In this model, learners should be familiar with the setting and the actions required in the setting. Such a setting can then be transferred into the classroom in the form of a contextualised problem. Although learners are now physically removed from the actual situation, the learners' model should be able to capture actions in reference to that setting, in a manner that will reflect the setting itself (referential). The next progression is for learners to develop mathematical relationships that relate to the setting (general) to becoming a mathematical model (formal). In this context, modelling becomes both a tool with which to describe another system and the examination of a relationship between a real or experienced world and a model. The idea is that one can generate mathematical meaning in learners by using informal, every day, contextualised referents as a gateway into decontextualized mathematical abstractions. This relationship is often described as a form of applied mathematics (Niss, Blum, & Galbraith, 2007), which requires of learners that they try to make symbolic descriptions of meaningful situations (Lesh & Doerr, 2003, p. 3-4). Some commend this relationship as a form of restoration between an original nexus that existed between mathematics and science (Hestenes, 2010). Treffers' (1987) work in the Dutch framework of Realistic Mathematics Education has coined the term "horizontal mathematisation" to describe the move from the "real world" to the "mathematical model". Vertical mathematisation refers to more formal and abstract mathematical structures within the mathematical domain itself.

3.4.5 The teacher helps learners generalise

Aside from helping learners institutionalise their knowledge, teachers also help learners seek generalisations. In this respect, modelling shares ideals with cognitive education theorists (see for example Haywood, 2013, p. 28-33). A major goal for both parties is the ability to generalise concepts and strategies to unfamiliar situations. Consequently, they rely on practices such as process questions of how learners solved problems, requesting justification from the learners, challenging both correct and incorrect solutions, and promoting task-intrinsic motivation by paying attention to learners' dispositions, attitudes, and beliefs about learning. The need for generalisation is articulated in Lesh and Doerr's (2003) notion of working towards models that are powerful, shareable, and re-usable in new situations, and the ideal of transforming the *model of* a particular situation into a *model for* (Streefland, 1991, p. 235; Van den Heuvel-Panhuizen, 2000, p. 6) more general application through reflection.

3.4.6 The teacher believes that learners learn through modelling

Freudenthal (1988, p. 134) goes against the grain of traditional ways by asking teachers to accept the position that problem-solving is an educational process in its own right. In traditional teaching, there is the view that learners first have to learn the work before they can problem-solve. Modelling suggests that learners learn directly through problem-solving. Learning and problem-solving occur simultaneously and these processes are not confined to an if-then scenario where the learning of content precedes its application.

3.4.7 The value of modelling for teachers

From the discussions above, we can argue that modelling acts as a bridge between many ideas that are often polarized at school. To clarify, modelling connects contextualised situations and decontextualised abstractions, informal reasoning with formal reasoning, content with processes, knowing with doing, the individual mind with the group mind, oral narrative with the textual narrative, creative processes with optimisation, and structural and functional properties of mathematical situations. On balance, modelling's orientation towards connecting systems suggests a move away from the still dominant factory-based model of education and its view of breaking down learning into pre-allocated and predefined elements and then reassembling it in a predetermined fashion, to metaphors that are more dynamic, adaptive, and holistic in nature.

3.5 WHAT DOES MODELLING HAVE TO OFFER LEARNERS WITH SEN

Table 3.4 summarises the benefit of modelling for learners with SEN. Each of these points is discussed in the chapter below.

Table 3.4 The benefits of modelling for learners with SEN

A learning journey: • Beyond essentialism • Beyond mindless compliance • Beyond "Be quiet" • Beyond school • Beyond a personal sense of failure • Beyond token economies

Table 3.4

3.5.1 Beyond essentialism

Essentialism promotes the sentiment that we should "get rid of the fluff" and focus on what is really important, which is the core components of mathematics. With this in mind, essentialism warrants "back to the basics" drives and their use of reductionism to peel away mathematical layers and label these as non-essentials until only the very basics of the concept are left to learn and to teach.

Consequently, essentialism supports an insulating approach to task design where concepts are deconstructed into their most basic components that are then taught as isolated units in a hierarchical form of learning and in a bottom-up approach. Essentialists argue that without the basics, learners cannot proceed to the higher-order concepts and more complex reasoning tasks. From their perspective, content is foundational to concepts. Their process validates the notion that learners with SEN learn at a slower rate than their peers, rather than learning differently. A key point is that since learners with SEN can only manage small amounts of content at a time, their conceptual understanding, and consequently their mathematical reasoning, will typically lag behind that of their peers. In reality, this lag between learners with SEN and their peers grows more pronounced every passing year.

When essentialism is applied to this cohort, teachers and learners typically get caught up in a recurring loop of trying to remediate and consolidate fundamental basic skills, which interferes with progression to more challenging work. The loop being activated is that learners with disabilities tend to do less well in education, which then leads to them being given a lesser education. Having less of an education increases their levels of functional disability in society as they are more likely to be unemployed, face poverty, and be excluded from societal opportunities The argument being made is that using essentialism in special needs education, restricts learners' access to only certain learning experiences, which in turn limits their educational attainment and increases their disability status in the eyes of general society (adapted from Powell, 2004, p. 2-3).

Modelling shares with Vygotskian curricular theorists such as Davydov, the ideal of holism. Both parties adopt a stance of elaboration against reductionism by encouraging cross-disciplinary themes. All things considered, they see mechanistic thinking and its emphasis on specialization and compartmentalisation as ineffective in handling complex problems. For this reason, their thinking promotes a shift in curricular design away from essentialism to holism, away from trying to understand concepts by breaking them down into their primary constituents, to beginning to understand concepts by focusing on the interaction and relationships between them. Consideration is given to the function and behaviour of the mathematical system as a whole and not so much on its static structural properties.

3.5.2 Beyond mindless compliance

A core example of the clash between the technical nature of evidence and democratic values is found in special needs education with direct teaching and its expectation of compliance. A difference between constructivist and explicit teaching concerns the levels of learner agency and learner guidance. Societal institutions that value self-determination as normative and that place importance on cultural issues will be more inclined to support alternatives to direct instruction. For example, from a Quality-of-Life organisational perspective, the greatest inhibitor for learners with SEN, according to Schalock (2010), is using an educational model which is "based on personal defectology, control and dependency, and that has a mechanistic orientation" (p. 3). There are concerns that direct teaching techniques may encourage learners with SEN to be too comfortable by replacing their own thinking with the thinking of others, thereby encouraging them to compliantly accept, follow, and practice the views of others. Chomsky (2000, p. 2) provides a much more detailed and passionate stance of the debate by discussing the paradoxical tension inherent in instructivist schools. He argues that this type of instruction focuses on indoctrination by blocking independent thought and by imposing obedience through control and allows the elite to continue their rule of society. For the most part, there is concern that direct teaching unintentionally fosters traits that may increase the already high propensity of learners with SEN for abuse, exploitation, learnt helplessness, and victimisation.

In like manner, self-determination is recognised as an important element of special needs learning curricula. Self-determination theory (Deci, Vallerand, Pelletier & Ryan, 1991, p. 327) recognises three basic psychological needs that are inherent in human life, namely, the needs for competence, relatedness, and autonomy or self-determination. Competence is supported by providing optimal challenges and performance feedback; relatedness refers to positive relationships such as parental involvement and peer acceptance; and, autonomy refers to an environment where control is lessened. Modelling has much more room and scope for the practices of autonomy than more instrumental approaches when used for the teaching and learning of mathematics. To explain, the notion of problematizing or mathematizing provides a supportive framework for self-determination. Focusing on the learner owning the problem offers choice, minimises controls, and makes conditions available to support the learner's own decision making processes and task performance. Self-determination theory holds that in environments where self-determination is promoted, participants will show greater levels of creativity, cognitive flexibility, and self-esteem (Deci, *et al.*, 1991, p. 342), which are also marks of research outcomes from modelling. Considering modelling's innate orientation to autonomy, these similarities are not surprising.

3.5.3 Beyond "Be Quiet"

As was explained earlier, modelling promotes communication at many different levels — working with others, working with ideas, and working with multiple modes of communication, for example, written language, oral language, symbolic language, pictures, and diagrams. It is hard to emphasise adequately the importance of developing language in learners with SEN. To illustrate, Ware (2014) states that "communication and language continue to be regarded as being at the heart of the curriculum" (p. 497) for learners with SEN. She also reminds us that communication is not only about language development, but that it is about two-way social interactions that need to transfer to real-life settings. By interacting with others during modelling tasks, learners discover how to use language to explain new experiences and realities and, in so doing, construct new ways of thinking and feeling about mathematics.

3.5.4 Beyond School

Another key debate in SEN circles is the "school-for-life" and "school-as-life" theme. With this in mind, Stangvik (2014, p. 92-93) discusses how in neoliberal discourse, since knowledge is tied to national economic competitiveness, schooling becomes directly linked to employment and productivity. There are further implications for special needs in that social welfare policies are expected to be replaced with the notion of self-capitalizing over a lifetime. In the light of a market setting, the curricula have to have cultural and utility value; in other words, the learner must not only find a place to belong in society for well-being reasons, but the ideal is for the learner to enter the workplace to move towards economic self-sufficiency. Curricula have also shifted to an emphasis on producing ability, rather than on teaching the abled and training or caring for the disabled.

I concede with the position of the cognitive flexibility model that direct teaching and its focus on memorising and following routine is ideal for well-structured situations in which little change over time is anticipated, and therefore well suited to a modernistic, industrial-based, factory model of society. However, the argument is also that society has changed in structure, and that preparing learners for acting out set routines is no longer applicable to their lives. Castells' (2002) view on the new information age and its impact on the development of a global economy is relevant here. It is currently posited that over the last three decades the world has entered into a post-industrial age. In this era, older industrial society models are crumbling under the pressure of an "information age" that requires new cadres of workers who can effectively deal with the dynamics of vast amounts of information and increasing levels of knowledge now available to society (Lyon, 2005). Not everyone (see Bertot, 2003; Friesen, 2009) supports the notion of a postmodern knowledge economy driven by information in digital form. Yet, it is important to realise that the debate around the knowledge economy is part of a much larger perspective, which is that any significant changes to the economy will invoke arguments around the interrelated sociological, philosophical, and psychological structures of mental activity.

In the final analysis, I am dismissive of a basic-skills curriculum, which is oriented towards procedural skills, without the development of higher-order thinking and problem-solving sensitivities. I concede that such a curriculum will create a serious problem for special needs learners once they enter into the workplace, as the ideas and concepts which are untaught or de-emphasised or considered "too challenging" are the very ones that special needs learners will have to face head-on, but now with impoverished and inadequate preparation.

.3.5.5. Beyond a personal sense of failure

Traditionally, success has been associated with mastery, for example, the mastery learning approach of Bloom (1968) when, for example, in mathematics, learners were typically given problems and also the pre-determined algorithms to solve the problems. Learners had to practice the given routine until they mastered it in over 80% of the assigned content. As was indicated above, this is a very safe routine for enculturating learners into a modernised industrial setting.

However, in modelling, success is no longer associated with mastery of established content and procedures. Rather, learners can be assessed on processes such as beginning to understand the knowledge that is being explored, engaging with content in problem-solving acts, developing an ability to critique work, increasing their expectation of taking up a position in relation to both their prior experience and new knowledge, engaging with complexity, ambiguity and analysis on multiple levels, and taking on new challenges. Risk-taking among participants is promoted through presenting continual "what-if" situations. Through these processes, learners are enabled to understand their own situations and frameworks, to experience actions and their consequences in the form of action and reaction, and to perceive how they learn.

I suggest that mathematical modelling allows for an alternative approach to dealing with human error that is far less threatening (and less damaging) to the learners' academic self-concepts. To explain, I use Reason's (2000, p. 768) view that systems approaches, which modelling is, allow for an approach to human error that is more model-centred than person-centred. In a model-centred approach, attention is given to the model by examining which areas are vulnerable and by considering consequent modification. It is not about eliminating the wrong in search of the right. Rather, it is finding a balance between conflicting pressures through navigation, negotiation, and synthesis of messy bits and pieces. In this context, errors become useful psychological processes and not maladaptive and irrational tendencies. A model-centred approach recognises that correct performance and error come from the same cognitive source and may be sides of the same coin (Reason, 1991, p. 2).

In contrast to the system's approach, the person approach to error (Reason, 2000, p. 768) is more typical in the traditional classroom setting. In this approach, the focus is on the errors of the individual, blaming the learner for forgetfulness, inattention, or moral weakness. When learners arrive at the wrong answer in mathematics, it is common to assume that it must be their fault. They did something wrong, did not pay attention to particular details, or they may be perceived or perceive themselves as not having the innate ability, that is, being mathematically weak.

3.5.6 Beyond token economies

Authors such as Greene (2009) argue that learners with emotional and behavioural problems benefit more from a solution-focused model than from behavioural shaping from token economies. With this in mind, modelling provides a framework to strengthen learners' abilities to work with solution-focused approaches, inasmuch as they learn how to work with open-ended problems, negotiate multiple perspectives, communicate and verify potential solutions.

3.5.7 Summary

We know from research in mainstream settings (Schoen,1993; Boaler, 1998; Riordan & Noyce, 2001; Clarke, Breed & Fraser, 2004;) that mathematical modelling learners do at least as well, and often better, on standardised tests; are more able to transfer mathematical ideas into the real world; are more confident in mathematics; display more evidence of adaptive intelligence than routine expertise when problem solving; value communication in mathematical learning more highly than learners in conventional classes; and, develop more positive views about the nature of mathematics than their counterparts in conventional classes.

Given that the learners are already displaying strong elements of disengagement, demotivation, and difficulties in adaptive functioning, transfer, and problem-solving, potential gains such as these should be actively pursued by giving learners the opportunity to model. At the very least, modelling should only be dismissed based on evidence from the research field after its implementation and scientific investigation.

3.6 LIMITATIONS OF MODELLING FOR LEARNERS WITH SEN

Modelling is not the panacea for all of special needs ills. It has its own set of limitations:

- Like other learners, learners with SEN will need time and patience to learn how to deal with the complexities around developing shared knowledge. Especially at the beginning, time for mathematical learning will probably be taken up by learning skills unrelated to mathematics.
- There are a lot of processes that may not necessarily be successfully negotiated between members during modelling, such as negative social dynamics or power differences between members, which could result in an overall knowledge loss rather than knowledge gains.
- Little is known about group cognitive processes, including group metacognition. Some authors argue that a group dumbs decisions-making processes down; others argue that groups help us to make smarter decisions.
- There needs to be wider buy-in from schools to prevent modelling from being regarded as a fad.

In addition, Ben-Hur (2006, p. 74-75) gives reasons why teachers are generally against problem-solving as an instructional means. These reasons are equally applicable to modelling, seeing that modelling is a form of problem-solving. Accordingly, teachers may reject modelling on the assumption that:

- Modelling is too difficult for many learners.
- Modelling takes too much time (not enough time in the curriculum for problem-solving).
- Modelling is not tested on proficiency tests.
- Before they can model, learners must master facts, procedures, and algorithms.
- Appropriate modelling problems are not readily available.

3.7 DOES THIS MEAN MATHEMATICS FOR ALL?

The authors of ACARA (2013b) considered mathematics for all. They designed a national curriculum which has special needs concerns embedded into it (Garner & Forbes, 2013), and mathematical modelling is included as a requirement from Foundation phase upwards. In the bigger scheme of things, we can say that we have achieved mathematics-for-all in policy, but not in practice. We can also say that we have achieved inclusive placement but not inclusive engagement in learning for all.

Yet, as I argued in the previous chapter, extending curricular options is not enough to secure genuine transformation and empowerment of learners and teachers. The social model on its own, and its promotion of social justice through equal treatment, equal curricula, and equal opportunity, has greatly diminished potential if it continues as a stand-alone entity without confronting the make-up of learners with SEN. These statements are grounded in Feuerstein's theory of structural cognitive modification. To this end, I concur with Feuerstein that some learners with SEN have significant difficulties that cannot be ignored but need to be addressed. In making this claim, I do not go as far as the earlier more pessimistic medical models in pathologizing learners and in pronouncing the return of fixed-ability, nor do I go as far as the social model in trying to state that these difficulties should be overcome by changing the environment but not by changing the learner. In line with the transactional models, I argue for change in both — environmental conditions need to change and the cognitive functions of learners with SEN need to be strengthened so that they can benefit more from the changed environment. I maintain there is a strong connection between the internal resources of the mind and the external resources of the classroom. Both need to be modified before the balance of forces will shift in the direction of greater quality of learning for learners with SEN. Accordingly, I argue that we identify the reality of social challenges like reduced curricula as a hallmark of special education AND recognise that learners with SEN have real histories and real difficulties when it comes to their learning. In light of these challenges, I take the argument further by saying that in spite of the best intentions of inclusion to improve the quality of their learning through diversifying the knowledge of the teachers, the differentiation of the curricula, and the extension of presentation and representation modes, and taking into account the effects of these learners' functional and structural brain changes, they may not necessarily benefit or be able to successfully cognitively access and process information in a mainstream environment.

3.7.1 The way forward

Essentially, I am proposing that modelling be used as a platform for mathematical teaching and at the same time as a platform for cognitive instruction as a means of restructuring cognitive functioning in learners with SEN. Put differently, we infuse cognitive instruction into the design of modelling tasks so that our design draws out cognitive functions for the purpose of strengthening these as well as enabling learners to solve challenging mathematics problems through mathematical content and strategies.

Table 3.5 shows the compatibility between what Feuerstein considers to be the purpose of cognitive functions and how modelling requires and activates these processes.

Table 3.5 Compatibility between Feuerstein and modelling

Feuerstein - purpose of cognitive functions (Feuerstein *et al.*, 2010,p.2)	**Modelling - purpose of modelling**	**Authors**
To recognise and produce cognitive conflicts	Identifying the problem	Dewey (1933/1991), p. 100
To decide what to focus on, when to focus, and in what ways to focus	Selecting relevant variables	Blomhøj and Jensen (2003)
To organise and sequence information	Building the model	Freudenthal (1971)
To connect diverse and disconnected experiences	Expanding the model	DiSessa (1998)
To communicate our experiences	Communicating the model	Swan (2006)
To adapt our experiences to new conditions	Testing the model against reality	Sekerák (2010)
To control the environment at greater distance	Generalising the model	Streefland (1991), p. 235; Van den Heuvel-Panhuizen (2000), p. 6

To increase options in dealing with the world	Increasing adaptive reasoning Increasing the meaning and role of mathematics (relevance) to the real world	Doerr and Pratt (2008)
To access affective, emotional, and attitudinal dimensions	Feeling positive about mathematical learning	Boaler (2008)

Table 3.5

Authors such as Howie (2011, p. 11-24) provides further support for the need for cognitive education in inclusive settings as a means to strengthen thinking skills. Her work reiterates much of what has been noted in this chapter, for example, that the mandate to promote thinking skills in learners is commonly supported in countries' national curricular statements, that developing thinking skills is necessary to promote real inclusive practice, that it will help learners prepare for academics but also for life by coping more positively with change, and that cognitive education is positive and optimistic in its outlook towards learners with SEN.

On the other hand, Harpaz (2007, p. 1852 Kindle edition) cautions teachers that cognitive interventions and methods of their implementation can go awry when teachers instruct on the strategies without actually cultivating them. Needless to say, talking about the topic instead of developing the skills themselves is counterproductive. Moreover, he points out that when cognitive strategies are infused into curricular programmes, as I do in my own designs, there is the potential for the strategies to become locked into that domain and consequently not transferring to other situations.

I propose that the way forward in using modelling as a form of cognitive education is to consider the modelling environment with its phases as a ZPD and to use it for the purposes that Vygotsky intended, which are:

- dynamic assessment to see if learners have the potential to learn from modelling
- the development of emergent cognitive functions, where the cognitive functions are taken as Feuerstein's list of cognitive deficits

- the joining of intuitive and scientific knowledge in ways that facilitate both their practical application in life while maintaining academic integrity

3.7.2 What would this look like in inclusive practice?

As noted earlier, Feuerstein believed that cognitive functions can be strengthened through mediation. To this end, he (Feurstein *et al*., 1988) stated that mediation can assume two forms — indirect mediation and direct mediation. Indirect mediation requires that the mediator creates conditions that will penetrate the learners' cognitive systems and help them register important variables and build relations between them. In this study, indirect mediation would be accomplished through the design of modelling tasks to the end stated here. On the other hand, mediators could work directly with learners by positioning themselves, physically or otherwise, between the learner and the modelling task, for example, by pointing, focusing, and selecting. The second instance relates to the modelling phases of the learner where, in the event of the learners not making progress with the instructional designs, educators will have to step in and mediate their cognitive functions in a direct manner.

Does direct mediation mean that we are back to direct teaching? The question could be debated from different angles. In the final analysis, we are talking about Vygotsky's idea of joint activity in the ZPD where the mediator makes the tools available on the social plane before the child internalises them on a physical plane. The bigger question then is whether Vygotsky really was a constructivist or whether his view of working in the ZPD aligns more with that of explicit teaching? All things considered, Vygotsky (1935/2011) seemed open to different methods being applied within the ZPD:

> Different researchers and authors use different methods of demonstration. Some demonstrate a complete problem-solving process and then ask the child to repeat it, or start the solution and then ask the child to continue, or ask leading questions. In a word, in different ways, you prompt the child to solve

> the problem with your help. (p. 203–204)

Consequently, all the learning strategies ranging from those derived from behaviourism through to situated cognition can be used in the ZPD, depending on the response of the child to the intervention.

My own view is that explicit teaching is more about teaching the content, whereas the direct mediation in Feuerstein's context is related to the cognitive functions themselves. Mediators intervene directly into the cognitive functions, which will allow the learner to become more independent in terms of dealing with the content of the task. Feuerstein (n.d) states:

> The intentionality of the mediator is different from that of the teacher. The mediator is not concerned with solving the problem at hand. Rather, the mediator is concerned with how the learner approaches solving the problem. The problem at hand is only an excuse to involve the mediator with the learner's thinking process. (p. 558)

3.7.3 What does it mean for instructional task design?

We know that learners with SEN typically have illogical, disorderly, and deregulated brain states, which is now made visible through Perry's brain map. Feuerstein reminds us that because of these brain states learners with SEN tend to have restrictive brain patterns, which limits their opportunities for successful adaptive behaviours and that they possess meagre cognitive resources to initiate sustaining change. The end result is a low level of functioning in comparison to age-related peers. The good news is that both authors argue that the nervous system has plasticity, meaning that it can begin to restructure itself. Consequently, brain function and structure can change based on environmental experiences. Although Feuerstein *et al.* (2010)(Section 2.7) argues from a top-down perspective and Perry and co-workers (Perry & Pollard, 1998)(Section 2.4.3.2) argue from a bottom-up perspective, essentially they believe in the same principles. I explore their principles for functional restoration of brain states by comparing them to each other and by showing how these principles are incorporated in UDL rationale (Section 2.3.3.1) as well in Table 3.6.

Table 3.6 Principles for instructional design to strengthen cognitive functions

General principles running through "brain rehabilitation"	**Feuerstein *et al.* (2010)**	**Perry & Pollard (1998)**	**UDL (Hall, Meyer & Rose (2012)**
Sensory processes are linked to higher-order cognitive processes	Intentional interactions are necessary to help the body regulate sensory input into patterns and order	Environmental experiences need to provide rhythmic somatosensory activities towards regulation	Activate sensory and motor networks through multiple representations (recognition network)
Relationships are important in facilitating connective change	Feuerstein and cultural mediation	Perry and attachment theory	
Reasoning should be strengthened	Address cognitive deficits through mediation	As lower parts of the brain stabilise through rhythmic somatosensory input, followed by relationship building, the higher parts of the brain will become more stable and susceptible to academic interventions	Activate executive control mechanisms (strategy network)
Learners should enjoy learning activities	Four dimensions: Input-elaboration-output AND affective motivational component	Use activities that the learner finds rewarding	Multiple modes of engagement (affective networks)

General principles running through "brain rehabilitation"	**Feuerstein *et al.* (2010)**	**Perry & Pollard (1998)**	**UDL (Hall, Meyer & Rose (2012)**
Certain systems of the brain are harder to change than others – less plasticity	Input phase behaviours are the hardest to change because of close proximity to sensory data	Lower areas harder to change than higher brain areas. The hardest area is the brainstem since it oversees important physiological functions such as heart rate, which is a necessary component of survival. Survival components resist change.	

Table 3.6

Ultimately, it means that the modelling tasks I am designing for learners should allow for sensory-motor activation, relationship-building, and reasoning processes by drawing out cognitive functions that can then be strengthened through direct mediation, if need be.

3.8 CONCLUSION

In this chapter, I considered modelling as a form of mathematics-for-all through its inclusion in ACARA, as a theoretical orientation, and as a practical application in terms of the roles of the learners and the teachers. Thereafter, I considered how modelling could meet some of the wider needs of learners with SEN, and I listed some of the limitations of modelling. Last, I argued that for learners with SEN to benefit from modelling, we need to use modelling as a form of cognitive education in additional to using it as a form of mathematical education. I discussed what modelling as a form of cognitive education would mean in terms of practice in the classroom and in terms of instructional design. In the next Chapter, I discuss my own effort at designing modelling tasks for learners with SEN with regards to the content of this chapter.

CHAPTER 4
METHODOLOGY AND PROTOCOL DESIGN

4.1 INTRODUCTION (Re-iteration of the need for this research)

As was mentioned in Chapter 1, and is reiterated here for completeness' sake, educators are constantly looking for pedagogical approaches that will ensure effective and efficient classroom learning. In the space where special needs education overlaps with mathematical learning and teaching, direct instructional approaches are well-documented and well-implemented. An alternative to the direct instructional approach is mathematical modelling. Although mathematical modelling is recommended as a pedagogical method in ACARA, it is still by and large overlooked in practice and research. My own position is that mathematical modelling holds more promise for learners with SEN than is credited to it, but that the lack of modelling in academic papers and classroom practice makes this claim difficult to substantiate scientifically. Given that, my intention was to set up a learning ecology that conformed to the modelling approach. For this purpose, I designed a hypothetical learning trajectory (HLT) that I considered to be age-appropriate, developmentally-appropriate, culturally-sensitive, and research-informed at the same time. Additionally, I implemented the HLT in a SEN classroom to gain insight into the effect and value of learning mathematics through modelling for this cohort. With this in mind, the design research processes were supported with a case study approach to uncover initial conjectures about how mathematical learning occurs in a modelling context in a SEN setting by:

- providing an analysis of how the learners engaged in modelling activities based on a
- problem-centred approach with stated learning goals taken from the ACARA framework
- providing evidence of the participants' learning by analysing their characteristics, the
- processes they engaged in, and the representations they used,
- and analysing the support needed and provided to the learners

4.2 DESIGN-BASED RESEARCH

The first thing to remember about designed-based research (DBR) is that it tries to intervene in a real-world matter in a real-world context. Embedded in DBR is the motivation to move from an existing establishment into a preferred one through change or innovation (Simon, 1981; Simonsen *et al*., 2010). Consequently, it identifies a situation that needs improvement and starts working towards a solution. In essence, the purpose of this study matches Reeves, McKenney and Herrington's (2011) statement that "educational design research has the twin objectives of developing creative approaches to solving human teaching, learning, and performance problems while at the same time constructing a body of design principles that can guide future development efforts" (p. 55). In respect to Reeves *et al.'s* first objective, this study is about taking on the responsibility of designing modelling tasks for learners with SEN to support their mathematical learning. With this in mind, the research problem is to implement mathematical modelling activities into a SEN classroom, and thereafter reflect on design principles that could make this type of teaching and learning approach more accessible to special needs educators and learners with SEN. How can mathematical modelling tasks be done? Where does it work? Where does it become more challenging? How can some of the challenges be overcome? It must be remembered that while affording this cohort of learners access to modelling opportunities, the element of success in their learning will be to critically link to the issue of support through design. Assuming that, a large part of the study is to consider how to support learners with SEN in their learning by using and adapting sensible design principles from literature. At the same time, and per Reeves *et al.'s* second objective, interventions and their usefulness need to be related back to theory for it to become valid scientific knowledge and thus to be credible, both from a scientific and from a practice field. On balance, one of the main differences in assumption between DBR and traditional approaches is DBR's ambition to inform theory and practice simultaneously, whereas traditional approaches tend to tackle them separately (McKenney & Reeves 2013, p. 97). To this end, an integral part of the design process is to derive principles from research to inform general theory.

4.2.1 The DBR Family

Historically, Freudenthal *et al.* (1968, 1971, 1973) was one of the first forerunners of DBR in the Netherlands with his developmental research approach. Others, such as Brown (1992) and Collins (1992), worked on design experiments in America. Current DBR is viewed as a familial term with development(al) research, formative research/enquiry, engineering research, didactical design research, and, potentially, action research all falling under its umbrella (Van den Akker, 2013, slide 24).

4.2.2 When to use DBR

There are two problems that DBR attempts to solve, namely, the disconnect between educational and psychological research and actual practitioners, and the related situation that educational research has not had the same breakthroughs as other fields (Walker, 2006, p. 8).

In respect to the first situation, The DBR Collective (2003) argues that this mode of research is "important methodologies for helping us understand how, when and why educational innovations work in practice" (p. 5). We know that a substantial part of the theoretical framework that drives teaching is the work done in psychology and, particularly, educational psychology. Psychology and education have historically found it hard to talk to one another when it comes to on the ground "getting-the-job-done" applications. Many years ago, William James (1899) described the trap of thinking that there exists a straightforward relationship between psychological theory and educational practice:

> You make a great, a very great mistake, if you think that psychology, being the science of the mind's law, is something from which you can deduce definite programs and schemes and methods of instruction for immediate schoolroom use. (Part I)

Likewise, Broekkamp and Hout-Walters (2007, p. 203) expand on the reality of the credibility gap between educational theory and practice, and the dissatisfaction as a result of the gap. Educators want knowledge that is useful, meaningful, and relevant to their classroom situations. Since they do not see research as conclusive or practical enough, they take little notice. Models such as *Evidence-Based Practice, Knowledge Communities*, *Cross-Boundary Practices*, and *Research Developmental Diffusions* are all efforts to close the gap to some degree. So is DBR. These developments show that the drive to apply knowledge or to have knowledge that is useful in the classroom is perhaps as urgent as the knowledge itself. Consequently, psychologists are now called on to justify the ecological validity of their efforts, and there is a growing onus on teachers to show that their work has theoretical ties and that it is scientific (Sandoval & Bell, 2004).

With respect to the second situation that DBR tries to solve, which is the overall level of unsatisfactory educational attainments in many countries, some authors argue that the alienation between researchers and teachers is contributing to this state of affairs (Blessing & Chakrabarti, 2009; Reeves *et al.*, 2011, p. 55). On the positive side, Hattie's (2009) research is cited (Reeves *et al*., 2011, p. 56) to provide evidence that educational research innovations are being trialled in classrooms, yet the educational outcomes from the majority of these research initiatives are unsatisfactory, even disappointing. On balance, educational research is growing, trials are implemented in classrooms, yet performance measures indicate that we are still searching for educational research that is socially relevant. Again, the emphasis is on the need to find educational research that is meaningful, and consequently, socially responsible (Reeves, 2000).

The general purpose of DBR in education is to design new ways of intervention, which will direct policy and support more learning (Gravemeijer & Van den Akker, 2003; Walker, 2006). DBR tries to meet these objectives by providing on-site monitoring of the designed artefact and feedback on its success and failures, therefore evaluating the artefact's viability in terms of theory and classroom practice (Cobb *et al.* 2003). To explain, DBR promotes education change by investigating how the intervention works in classrooms by studying the mechanics of the intervention, the process of learning during the intervention, and the means needed to support the learning (Gravemeijer & Cobb, 2006, p. 449-473).

For the most part, there are specific instances when DBR is useful in classrooms and, conversely, when it is not. To clarify, DBR is useful when an intervention is novel or when an already existing mode of practice is not effective. On the other hand, Kelly (2010) reminds us that DBR is not useful when a practice is already established as being successful in a variety of settings or when the problem is closed in that "we know the initial states, the goal states and the operators of how to move from the initial states to the goal states" (p. 74-75). In colloquial language, "If it ain't broke, then don't fix it".

In like manner, DBR is better suited to open problems, where educators are grappling with issues of effective practice, assessment, and successful outcomes. Kelly (2010) refers to the type of problem that is most suited to DBR methods as "wicked problems" (p. 76). Wicked problems are characterised "by their solutions being frustrating or potentially unattainable, inadequate resources, no stopping rules or markers to indicate if a solution is at hand or whether the project should be abandoned, unique and complex contexts and inter-connected systemic factors that impinge on progress" (p. 76–78). To further clarify when DBR is appropriate as a research method, Kelly (2010) states:

> Design research is recommended when the problem facing learning or teaching is substantial and daunting and how-to-do guidelines available for addressing the problem are unavailable...There should be little agreement on how to proceed to solve the problem, and the literature reviews together with an examination of other solutions applied elsewhere (i.e. benchmarking) should have proven unsatisfactory. (p. 75)

As was noted earlier, DBR tries to build systems based on theory and then tests the effectiveness of these systems in practice (Walker, 2006). The theory that is used to inform the original system is typically drawn from the structure of the domain in which it is situated (Kelly, 2006). It is important to remember that DBR differs from more traditional approaches with regards to theory in that DBR is not about the direct application of theory to a situation, nor is it to test how good a predictor theory is of events, when it is applied to practice. Simply put, DBR is not suited as a testing platform for theories and their application. Nor is DBR a suitable platform for comparing interventions against one another.

Furthermore, the difference between DBR and design science is multifocal. For example, Simonsen *et al.* (2010) discuss how DBR is neither research based on a design, nor is it designing in its own right. It is not a design based on science, nor is it merely design science. It seems to fit more as a hybrid between research and design.

In reality, there exists doubt if DBR is capable of delivering on its promises, but, on the whole, recent reviews seem to suggest that DBR is advantageous to educators in that it is gaining in popularity as a tool amongst researchers, attracts funding, and tends to report improved learning outcomes and/or learner attitudes (McKenney & Reeves, 2013, p. 97).

In the final analysis, there is still much grappling around issues of effective practice and successful outcomes in special needs education in the domain of modelling. Little work has been done in classrooms and in research up to now, creating a clear gap between policy and practice and research. Taking the above factors into account, the dynamics make it a suitable research problem in the form of design-based research.

In Table 4.1 below, I compare this study to general principles of when to use DBR and conclude that DBR is a suitable methodology for the purposes of this study.

Table 4.1 Usefulness of DBR in general and its relevance to this study

General appropriate application and use of DBR	**Relevant to this study**	**Specific use in this study**
"Wicked problem" - still grappling with issues around effective practice, assessment and successful outcomes. Little known about the existing mode in practice (Kelly, 2010, p. 74-75)	✓	Gaps in research and practice in SEN classrooms with modelling (Diezman *et al*., 2012, p. 100)
Not comparing one intervention against another (Gravemeijer & Cobb, 2006, p. 473)	✓	Not comparing modelling tasks to direct intervention
Building a design based on theory (Walker, 2006) Not testing a theory or its application by measuring specific, predetermined effects of the approach on the learners Not an impact study - not deciding if the intervention caused a change or effect in the participants	✓	Creating modelling tasks for learners with SEN with the purpose to design-for-support. Support orientations drawn from theory, especially Feuerstein's theory on structural cognitive modifiability
To create a learning ecology to bring about new forms of learning (Gravemeijer & Van den Akker, 2003)	✓	Considers how to design modelling tasks so that learners with SEN can learn worthwhile, domain-relevant mathematics
Scientific approach to the design of an educational intervention (Simonsen *et al.*, 2010)	✓	Submitted to university as part of a PhD - qualitative analysis evaluation
Contributes to bridging the gap between research and practice (Broekkamp & Hout-Walters, 2007, p. 203 ff)	✓	Gap in research when it comes to modelling and learners with SEN. Exception Van den Heuvel-Panhuizen and her learners (2012)
McKenney and Reeves (2012, p. 172, Kindle) describe DBR as a natural fit with educational practices	✓	Main purpose of study is to improve my own practice as a teacher in relation to learners with SEN

Table 4.1

4.2.3 Working through the cycles of DBR

Unlike other forms of research, in DBR the relationship between the research and the design is not linear but circular. Put differently, the research moves continuously through distinct cycles. These cycles have been given various names and categorisations by different authors, but they generally involve a design, an implementation, an evaluation, and a revision period. For example, McKenney and Reeves (2012, p. 2010 – 4281 Kindle edition) describe the core processes of DBR as the analysis and exploration stage where the research focus is established, the design and construct phase where the creative solutions are mapped and implemented, the evaluation and reflection stage where ideas are shaped and tested and tried, and, finally, the immersion and spread phase where the practice base of the invention is broadened. Likewise, Nieveen, McKenney and Van den Akker (2006, p. 151) note that DBR works through multiple cycles moving from an exploratory phase at the beginning (speculation, observation, and identification) to a testing phase in the middle (trying out innovations and modifications) to a confirmatory phase (it improves learning or it does not) towards the end. An advantage of DBR's emphasis on phases is that it considers the whole process of scientific research, unlike certain forms of research that place more weight on the final phase of the research, for example, by focusing on results that confirm or disconfirm the initial hypothesis (Phillips, 2006).

From the options in literature, I have selected Reeves' (2000, p. 25; 2006, p. 1403) model given below as the basis for this study:

- Stage 1: Analysis of practical problems by researchers and practitioners in collaboration
- Stage 2: Development of solutions informed by existing design principles and technological innovations
- Stage 3: Iterative cycles of testing and refinement of solutions in practice
- Stage 4: Reflection to produce "design principles" and enhance solution implementation

Accordingly, Reeves (2000, p.25) describes the stages as the analysis of practical problems by researchers and practitioners, followed by the development of solutions with a theoretical framework, then an evaluation and testing of solutions in practice, and, lastly, documentation and reflection to produce general design principles.

4.2.3.1. Timeline of the cycles in this study

Below, in Table 4.2, is a timeline showing how Reeves' (2006) cycles were translated into this study across a 5-year period.

Table 4.2 Timeline showing how the phases of DBR materialised in this study

	Year 1	Year 2	Year 3	Year 4	Year 5
DBR Stage 1: Exploration of the problem					
Literature review	General literature to explore the problem		Discrete body of literature suited to problem	Data mining of specific relevant studies	Prepare for presentation
DBR Stage 2: Development of solutions informed by existing practices					
International workshops to develop draft elements	International workshop on modelling			International workshops on Feuerstein and DBR. First cycle of NMT training to use brain mapping	Continue with NME training
Discussion with practitioners, researchers and theorists Evolving product	Key concepts - no design elements		Draft elements of approach reviewed by practitioner consultation and panel review	Start designing elements specifically for study Discuss with cultural advisor	Psycho-educational profiles Screening Co-teaching Practitioner consultation Consultation with cultural advisor Expert review
Search for suitable research cohort	Began search for suitable school	International school Visa delays Relocate to new country in October	Familiarise myself with school, the curriculum, the cultural groups and dynamics		Get permission from the school to conduct the research in the second semester
Ethics proposal and instruments			Get permission from principal Start to develop instruments	Seek ethical clearance - many delays in facilitating different ethics committees Ethical clearance granted in December	Consult with cultural advisor; obtain consent from parents and assent (or dissent) from learners through mediator
DBR Stage 3: Iterative cycles of testing and refinement of solutions in practice					
Implement designs into classroom					Implementation in classroom (3 cycles)
DBR Stage 4: Reflection to produce design principles and enhance solution					
Prepare for publication					General design principles

Table 4.2

4.2.3.2 Research challenges associated with the timeline

My own time line illustrates Cohen, Peurach, Glazer, Gates and Goldin's (2014) point that whereas theoretical descriptions of improvement through DBR seem pretty straightforward in that there is typically a design phase, an implementation phase, and evaluation phase, followed by a validation phase and then a scaling phase, there is little evidence of this type of orderly and logical progression in practice. Instead, the process is more like a "collection of puzzles that can be understood and managed, but which often develop in an overlapping and non-sequential manner" (p. 616).

Another aspect of this study that needs to be noted is the very short time periods between the planning, implementation and evaluation, and revision of each design experiment or set of modelling activities (the mathematics challenges). There are several factors that contributed to this situation, which can be described in reference to the Timeline Table. One relates to specific research challenges, which diluted the amount of time I could spend between interventions. As this was an international study it took time to find a suitable school, and once a school was identified and approached, the international ethical gatekeeping processes required more extensive protocol than would be typical of a national study. Moreover, my visa was locked into the school that was sponsoring me, and its restrictions prevented me from extending the study into other SEN locations. Another influencer was the still empty cupboards in the current knowledge base on how learners with SEN respond to this type of intervention, thus making the nature of the study partly exploratory. As was noted earlier, for the sake of ethical conscience and in the interest of the learners with SEN, it was compacted into a relatively short time span. To clarify, learners with SEN needed to be protected should the study yield too many unintended consequences or outcomes that impeded rather than advanced their learning. Moreover, the objective of the study was in respect to the approach and not on the refinement of materials per se. In reality, the instructional tasks acted as the proverbial "means to an end", and not the end in itself. To explain, the purpose of the study was not to improve the actual mathematics challenges, as is more typical in DBR practice, although reflection on the latter is still necessary and useful, but to gain insight into how learners respond to modelling in terms of their learning. At the same time, I can perceive the benefits of this type of study as a longer-term research project where the macro-cycle (system/society/nation/state) consists of meso-cycles (schools) and micro-cycles (classrooms/learners). McKenney and Reeves (2012, p. 4291 Kindle edition) consent that it is acceptable that graduate learners' research proposals focus on detailed descriptions of micro or meso-cycles, whereas those submitted to funding agencies to obtain support would likely be required to describe macro-cycles.

Correspondingly, Herrington *et al.* (2007) note that DBR in its actual form is a lengthy process that should ideally take place over several years. For this reason, it may seem an unsuitable option for doctoral learners based on the time duration of the course. Yet, Herrington and her colleagues recommend it as a study methodology that should be attempted by doctoral learners despite its intensity.

It is important to realise that the relatively short time span between interventions affects the type of data that can be collected from the study. In this regard, Herrington *et al.* (2007, para. 22) observed that data from the earlier stages of DBR are more likely to contribute to contextual understanding, whereas data collected from the later stages are more reflective of user reactions. The former applies to this study and aids my purpose as a teacher of learners with SEN. From my perspective, having a deepened contextual understanding is significant as it affects my daily pedagogy and practice. And essentially, from the perspective of the then and there, that was my goal in doing the research. However, stopping in the early phases of DBR would be insufficient for some of the other goals of DBR related to producing design artefacts for agencies other than myself and my own classroom situation. To this end, it would be necessary for the research to be extended by increasing its triangulation to include a greater variety of data sources such as participants in different schools, or including more participants from the same school before its adoption and enactment by other professionals.

4.2.4 Supporting DBR with a case study approach

At present, the theoretical nature and methodology of DBR is difficult to pinpoint. DBR shares with traditional methodologies common goals such as descriptive, interpretive, evaluative, predictive, and action research directives (McKenney & Reeves, 2012, p. 784 Kindle edition). Yet, it is important to realise that there are little shared focal points around methodology in DBR. Some argue that this is because DBR still presents as very fragmented (Blessing & Chakrabarti, 2009). Others take a more positive stance. For example, Anderson and Shattuck (2012) describe DBR as "epistemologically agnostic to the type of methodologies used" (p. 17), which leaves it wide open to mixed methods and a variety of research tools and techniques. On the whole, DBR sanctions methodological pluralism. Like other research projects, DBR allows for researchers to let their research questions dictate their methodologies. I indicated previously that I will need rich detail on how the learners responded to the design in relation to their learning characteristics, processes, and representations. With this in mind, I chose the case study approach as my second vehicle of inquiry.

4.2.4.1 What is a case study approach?

Case studies focus on a very small number of cases in a real-life context to gain a deep understanding of the issues at hand (Yin, 2012, p. 4). Swanborn (2010) defines "small" (p. 14) according to a general rule of thumb as not more than four or five cases, and explains that means that the focus is on intensive investigation within a unit of analysis rather than on extensive research across many units. Moreover, the notion of working within a unit implies a bounded setting or a delineated object of study where the sense of boundedness is commonly obvious, for example, a person, a group, a community, and even a programme (Merriam, 2009, p. 40).

4.2.4.2 Why use a case study approach

A case study approach was considered as an appropriate secondary methodology for this study for several reasons. First, the size of the sample in this particular case is very small for reasons relating to the local school's setup where one special needs classroom typically accommodates between three and ten learners. Ideally, special needs classroom sizes are kept small in relation to mainstream setups to provide learners with more intensive educational support. Considering that some learners might not want to be involved in the research, this would reduce the sample size even further.

Second, the modelling approach is being evaluated against individualised outcomes and not group outcomes. In addition to capturing and describing the instructional processes, individual differences between participants' experiences and outcomes were documented. Moreover, what modelling meant to individual participants was recorded. In spite of the fact that learners with SEN may have the same disability, diagnosis, or label, behaviours and challenges in the classroom can present very differently for each learner. In other words, learners with the same disability can have varied and idiosyncratic learning challenges. The focus was therefore on investigating how the approach works with particular learners in a particular SEN setting. Correspondingly, case studies can produce high-grade, thought-challenging data to help answer what, how, and why questions in regards to each learner. For example, how did the learner's characteristics influence the design? Which cognitive deficits were strengthened and how? What support was given and why?

Third, the design in this study was still evolving, and not final. With this in mind, the case study methodology provides appropriate support for the designer-researcher, in that it supports documenting the influences on the design and explains the reasons behind subsequent modifications. By the same token, Bannan (2010, p. 55) describes that often very important data generated during the process of DBR, and especially during the creative design phase, are lost to others in the field. For others to capitalize on the data, there must be systematic record-keeping and documentation. All things considered, careful descriptions provide a platform for understanding the researcher's design decisions and actions during the DBR stages, in relation to learners' learning processes, among other factors. Additionally, rich and transparent descriptions of the study protect the design, achieve scientific credibility, and aid transferability to other contexts (Lincoln & Guban, 1985).

Lastly, one has to take into account the scope and the limits of the study. As was noted earlier, the earlier stages of DBR typically yield contextualised data and evoke more creativity from the designer when compared to the later stages. In contrast, since the later stages of DBR are more intent on the spread and diffusion of the intervention, the interest would be more towards common group outcomes, controlled conditions, and causality. To evaluate these types of objectives, quantitative data collection methods would prove more useful.

4.3 DATA PROTOCOLS: GENERAL PRINCIPLES OF DESIGN

The following parts of the study gave attention to the selection of general principles of design:

Task A: **Define the critical characteristics of learning environments for learners with SEN**

Task B: **Define the critical characteristics of modelling as an instructional task**

Whereas Task A considered inclusive principles from the perspectives of disability discourses, Task B analysed design requirements from the perspective of modelling. The respective analyses are documented in Chapters 2 and 3 of this study.

4.4. ADAPTING THE DESIGN TO A LOCALISED CONTEXT

My intent was to get to know the learners and then design instructional tasks that I thought would be suitable to them in their context. Before implementing the tasks, I engaged in a series of activities with the purpose of getting a multi-dimensional, intra- and interdisciplinary perspective on the situation:

Task C: **Establish the specific strengths and vulnerabilities of the research cohort**

Task D: **Design a hypothetical learning trajectory (HLT)**

Task E: **Pre-Evaluation:**

Screening, Co-Teaching and Tryout of Approach (not activities), Practitioner Consultation, Consultation with Cultural Advisor, Expert Consultation

For the purpose of gaining an insider perspective, I became both the teacher and the researcher. Yet, from the perspective of the "old-timers" in the community, in particular colleagues who have lived and worked in the Northern Territory for many years, I was still an "outsider".

4.4.1. My own professional experiences as a teacher

To gather an insider perspective, I worked at the school for two years before implementing the study. During this time, I prepared for the study by getting to know the school, the learners, and their families.

First, being new to the state, it was required that I move from having a provisional teacher registration to a full teacher registration. I used the processes of gaining full registration as an initial try-out of modelling in the school. To explain, the process of full registration at the time required five written classroom observations done by colleagues, followed by a reflective discussion between myself and the colleagues who observed my teaching. Additionally, at the end of the series of observations there was a panel presentation and feedback session on my teaching. My presentation consisted of evidence of teaching and learning from a learning sequence using modelling. The panel was made up of the local school's deputy principal for teaching and learning, the curriculum manager, the team leader of the SEN unit, and a colleague who taught mainstream. This was an opportunity to see whether the school endorsed modelling or not, whether my colleagues and leaders noticed any serious disadvantages emerging from my approach with respect to learners with SEN, and whether there were specific concerns with regards to curricula and teaching and learning issues from the school's perspective. I used feedback from the panel to draft a research proposal for the department and for local ethics committees. To summarise, the rationale behind the process towards full registration was to implement modelling tasks in my classroom, to participate in practitioner consultations leading up to a panel review, and to use the feedback from this process to draft research elements towards a formal study.

The second initiative sprang from the first. Once it was established that the school had a positive response to modelling, I incorporated the approach into my teaching load, one term per year. These experiences gave me the opportunity to reflect more deeply on data collection methods and instruments, and to become more sensitive to what learners with SEN would need from mathematical modelling tasks.

The third initiative was related to the families of the learners. My position as a teacher allowed me to work closely with the parents and carers of the learners. Attending

Education Adjustment Programme (EAP) meetings and case conferences gave me a good understanding of the learners from the parents and carers' perspectives. At these meetings, I made a point of consulting with the parents and carers on their views of how the particular learner should be taught and what strategies they thought needed to be introduced into the classroom to support the learner. Other aspects of classroom practice, such as regular phone calls to parents or carers and classroom morning teas for families, enabled me to establish a relationship of trust and genuine sharing of ideas about learners with their parents or carers, and with the learners themselves.

Being a teacher at the school facilitated a deeper understanding of the local context for which the designs were intended. For example, by being part of the staff and through the daily routine and the professional development sessions, I developed an awareness of how aspects of schooling were organised and prioritised, what the demographic and cultural parameters were, and which aspects of teaching and learning the school valued. During this time, I was able to identify and build relationships with people who I could approach to assume the role of "critical friends" during the research. Becoming known to the school, and to the community through the school, eased the facilitation of the research process. The school's familiarity with me helped to reduce incidences of reactivity from the learners to the research and its conditions.

At the same time, I concur with Hammersley (2002, p. 218-220) that each of these processes can equally serve to undermine the validity of the research in that they can foster self-deception by, for example, relying on implicit rather than explicit knowledge sources and by being too exclusive in selecting collaborators and in the process eliminating others who would be worthwhile critics.

Be that as it may, design cannot be framed as a singular, point-in-time solution but as an ongoing activity involving several important relationships and negotiations. In reality, the process of confronting design creates both strengths and vulnerabilities in relationships — between researchers and schools, and between researchers, schools and the broader community — all of which need to be managed (Cohen *et al.*, p. 655).

4.4.2 The school setting

Although aspects of the research were considered earlier, I will repeat some of the information here for the sake of completeness.

The study took place in a special education setting attached to a mainstream middle school. The school is a public school, with a large proportion of clientele from lower- and middle-class families. The community that feeds into the school has on-going challenges common to historically oppressed minority cultural groups, including alcoholism, previous generations with very little schooling, racism, and domestic violence. The school supports a full-inclusion policy and tries to cater for diversity by offering multidimensional educational tracks for learners. To this end, it has a mainstream setting, a flexible learning centre, and a special needs centre. Taken as a general rule of thumb, the mainstream school caters for the education of general learners, the flexible learner centre hosts learners who have no known cognitive disability and/or learning difficulties yet struggle to manage mainstream environments largely because of emotional and behaviour challenges, and the special needs unit accommodates learners with confirmed cognitive disability and/or other disorders that significantly inhibit their learning. Whereas the school allows for learners to move between units, the process of reintegrating learners from the flexible learning centre and the special needs centre back into the mainstream setting, albeit in a part- or full-time capacity, presents its own set of challenges, which is not part of the scope of this study. The school has adopted the RtI model (section 2.4.3.1) and has made a renewed commitment to improving the quality of teaching, both as a way to raise levels towards national standards and as a means to cater for diversity. To this end, they are part of the provincial government's initiative to implement the *Visible Learning* programme to bring about school-wide reform in teaching and learning as well as to establish evidence-based practice (Section.2.5.2.2) With this in mind, the school has made the significant effort of collecting school-wide data by assessing each learner's level of literacy and numeracy, and by holding teachers accountable for delivering evidence of learner achievement and progress with respect to the data. In addition, the school uses the *School Wide Positive Behaviour Support (SWPBS)* programme, which is essentially a programme with principles from behaviourism (Section 2.5.1.1) aimed at reducing challenging behaviours of learners. Typically, the school has a large cohort of teachers between 25 and 35 years of age and a relatively large turnover of staff every year. For the most part, the school is described as "well-resourced" in terms of its staff, its structures, and its digital resources.

4.4.3 The special needs unit

In the next section I discuss the features of the special needs unit in the context of the local school used in this study.

4.4.3.1 The entry policy

As was noted earlier, in the context of this research project, the decisions of who is a learner with SEN is dependent on government policy, the Northern Territory Policy on the Enrolment of learners with disabilities in special schools and special centres (Section 1.3) (Department of Education and Learner Services, 2012). Accordingly, for learners to be placed in a special centre requires a formal diagnosis that shows impaired cognitive functioning, deficits in two or more adaptive functions, and an intellectual level below average.

A challenge emerging from the policy stance is the requirement of a formal diagnosis or label. As was noted in an earlier chapter, in spite of the disenfranchisement with labelling (Section 2.4.2.2 (i)), labels are still the primary vehicle for getting learners the assistance and resources that they need in a school setup. Without these, learners are not able to access the special centre services nor are they able to access additional government funding to support them at school. To this end, the system's formula resembles a very clear chain of reasoning: no diagnosis = no funding = no additional support. In other words, Goldstein, Arkell, Ashcroft, Hurley, and Lilley's (1975) reference to a label as the "passport to special education" (p. 17) is still relevant and applicable today. Since access to psychologists is scarce in this part of Australia, the school hires a private psychologist to conduct assessments at set times throughout the year.

It is important to realise that the current policy stipulations give precedence to disability, and in particular to cognitive impairment, by excluding learners with emotional-behavioural challenges and learners who are disadvantaged in a school setting because of cultural-linguistic factors and/or socio-economic circumstances. Equally important, the perspective of the policy suggests a strong alignment with the medical model (Section 2.2.4) by basing special education on the fundamental assumptions that disability is a condition that individuals have, that a disabled/not-disabled distinction between learners is useful and objective, that special education is a coordinated system of services that helps learners who are labelled, and that progress in the field is made by improving diagnoses (Bogdan and Kugelmass, 1984, p. 178–179). Although the policy for entry into SEN units appears rational in its orientation, I find its restrictions on special education positivistic and reductionist in nature, and I prefer to align myself with broader, more inclusive definitions of special education to include learners who are finding negotiating school environments challenging with or without a formal diagnosis.

4.4.3.2 The entry procedures

In accordance with the RtI model, the school considers general teaching in the classroom as tier one. Second wave learners are accommodated in resource rooms, where programmes such as *MultiLit* and *QuickSmart* are run by paraprofessionals to assist these learners in closing the gap. The learners in the research sample largely fit into the third wave or tier where they are identified as individual and intensive intervention and where they have been referred for psychometric testing. To explain, learners are placed in the special needs unit after mainstream teachers have made the recommendation for referral, a specialist such as a psychologist or medical practitioner has confirmed a diagnosis, and parents and carers were consulted and gave consent for the transfer from mainstream into a special needs unit. In the context of this study, the cohort of learners has proverbially speaking "been through the mill". In other words, these learners did not achieve the measures of success hoped for in a general classroom and for this reason they tend to enter into the SEN unit with a long history of academic failures trailing behind them.

4.4.3.3 The characteristics of the unit

As per trends noted in literature (see Section 2.3.1), the special needs unit of the school represents a disproportionate number of minority group learners and male learners. The unit has grown from one to six classes over the period of three years since it was first established. Class sizes in the unit average between three and nine learners. Typically, each classroom has a teacher and a LSA. The teachers and staff work fairly closely with the Student Services Division with respect to EAPs. The lesson structures run off a timetable and are each 55 minutes long. Learners typically have mathematics every day after recess. Learners with SEN stay in their class with their class teacher throughout the day, except for the times when they attend mainstream classes for specialised subjects such as *Art, Design and Technology, Multimedia, Gardening and/or Cooking.* They do not join mainstream classes during these sessions, rather they are taught by mainstream teachers in the mainstream section of the school to facilitate release time for SEN teachers.

4.4.3.4 The sample from within the unit

I worked at the school as a teacher and wanted to use my class in the study for several reasons. These included convenience, but more importantly, it is my experience that behaviours of certain learners with SEN change when newcomers are introduced into settings. In other words, some learners respond differently to someone with whom they are familiar than how they react to a stranger. Moreover, the fact that the learners were familiar with me and I with them helped me to personalise the design to our context. Additionally, by having my own class participate in the study, I had more time with the learners during the day to evaluate the overall effect of the intervention from a perspective that would not be possible if the learners were not with me during their school day. For example, I could document examples of spontaneous transfer of their mathematical learning to other classroom activities. On the negative side, being the teacher of the class creates ethical issues such as the power imbalance between the learners and the teacher-researcher. These ethical issues and how they were addressed are discussed in detail near the end of this chapter (Section 4.10).

Patton (2003, p. 5) distinguishes twelve different types of purposeful sampling strategies. From his list I have selected the following as applicable and relevant to this study:

- Typical case sampling. The cases that I have selected to write about in the research represent some of the more typical profiles common to SEN classes, namely, autism, global developmental delay, and foetal alcohol syndrome.
- Maximum variation sampling. I have purposefully picked a wider range of cases as opposed to autism only, for example, to get a variation on different profiles of learners with SEN, and how learners with different levels of mathematical abilities respond.

The way the learners were invited to participate in the research is discussed at length in a later section of this chapter (Section 4.10). For now it will suffice to say that the families were contacted and the research was discussed with them, following which the learners of the families who gave their consent were invited through a mediator to participate. Only in cases where both the families and the learners themselves agreed to the study, were data collected from the learner and analysed for the purposes of the study. At the same time, all learners in the class (nine in total) participated in the activities as per their normal mathematics lesson for the day.

4.4.3.5 The class itself

i) Physical layout

For the last one and a half years I have been training in the NMT/NME model (see Section 2.4.3.2) and have been grappling with the meaning of their principles as it applies to classroom practice. With this in mind, I made an effort to increasingly reflect these principles in my own setting. For example, to allow for rocking movements, I have a swing chair in my classroom of the type one would normally place in a garden, a porch, or on a patio. Additionally, there are several swivel chairs that can rotate 360 degrees, a couch in one corner with a soft blanket on it, and several bean bags scattered around the room. In the middle of the room there are two round tables where the learners do group work. The learners also have individual tables along the side of the classroom walls. Lastly, the room has a side room adjacent to it, almost like a study, which contains a table with a few chairs and two steel cupboards against the wall to store classroom resources.

ii) Staff

I worked with a LSA who is with the class all day in a full-time capacity. Her role is to support the learners by assisting them with tasks where necessary, dealing with behaviours, and building positive relationships. She is not assigned to a particular learner but to the group as a whole and accompanies the learners wherever they go, that is, to different teachers and classes, throughout the day. During our discussion of the research prior to its launch, I asked that she assume a minimal role by not helping any of the learners with the task itself, that is to take care not to "solve the problem for them". For the most part, she assumed the role of an observer, watching from the side of the room as the learners tried to solve the problems, while occasionally chatting with them and checking up on their well-being.

4.5. A DISCUSSION OF THE INSTRUMENTS USED FOR THE PROFILES

Data were collated to construct a psycho-educational profile that would show critical characteristics of the learner with respect to his or her learning. These data were useful before the implementation phase of the study to plan designs that would be appropriate for the learners, in so far as they contained information on the learners' developmental levels, their strengths and interests, their barriers to learning, and previously taught aspects and levels of mathematics. During the implementation phase of the study, I relied on the content of the psycho-educational profiles to guide the types and measures of support given to the learners during the mathematical challenges. At the end of the study, the data were used with respect to the following research question: *What is the relation (if any) between a learner's learning behaviour during mathematical modelling and his or her psycho-educational profile?*

It is important to realise that the documents in the school file represent additional processes such as EAP meetings, case conferences, and assessments done from a consultative and from an interdisciplinary angle, typically involving parents or carers, health workers, social welfare personnel, and school personnel.

There was one particular challenge with the data in the files which is that preference is given to delivering specialist intervention services to learners during the early childhood years. Once learners enter into middle school, there is a marked tailing off of the interaction between the learners and these services. Under these circumstances, there are very little up-to-date assessments concerned with additional therapeutic interventions, for example, current speech and language reviews. As a general rule of thumb, we compensated for this in our unit by using a multiple perspective approach, thereby asking the different representatives at the EAP meetings if they had noticed any particular difficulties with regard to a certain issue, such as speech, health, or fine motor skills. Table 4.3 contains a list of document sources from the learners' school files that was used in this study. Each of these categories is discussed in more detail below.

Table 4.3 A list of the sources used to compile the learners' psycho-educational profiles

Documents in school file	**Instrument**	**Purpose**
School reports, assessments from health practitioners, EAPs	Timeline showing concerns and interventions with learners	Developmental history
Neurosequential Model of Therapeutics brain map	Neurosequential Model of Therapeutics questionnaire	Visual "map" of brain structure and function, depicting strengths and vulnerabilities
The Assessment of Lagging Skills and Unsolved Problems Tool (ALSUP)	The Assessment of Lagging Skills and Unsolved Problems Tool (ALSUP) questionnaire	Current challenging behaviours that affect classroom behaviour and learning

Table 4.3

4.5.1 Documents in School Files

A range of documents from the school files have been consulted. Depending on what was available in the file at the time, it typically involved:

- reports, assessments, and recommendations from specialists including paediatric, psychological, occupational therapists, speech and language therapists,

physiotherapists, and learner welfare sources
- school progress reports
- attendance records
- case conference notes
- incident reports
- EAPs
- Health plans, including the dispensing of medicine

These documents provided a history of the learner's progress at school, developmental difficulties, strengths and vulnerabilities, personal interests, barriers to learning, and previous and ongoing interventions and support mechanisms.

4.5.1.1 The NMT brain map

As was noted above, the school wants educators to work increasingly with data as a way to establish evidence-based practice in classrooms. As was documented by others (see Section 2.4.3.2 (ii)), I find using data that are based on standard academic tests and, in particular, on literacy and numeracy attainments very limiting in portraying a more holistic and balanced evaluation of the progress that learners with SEN are making at school. For this reason, I explored alternative options of demonstrating development and growth in a SEN learning environment. Put differently, I was considering alternative frameworks as a means to providing more holistic and comprehensive accounts of key aspects of development, which could inform my understanding of the potential, the progress, and the performance of learners with SEN on a broader level than was possible by analysing reading and mathematical scores alone.

With this in mind, I adopted Perry and his associates' (Perry & Hambrick, 2008) functional brain map tool for assessing and examining the presence and functional status of various brain-mediated functions. The map is generated from a questionnaire, which in my context is completed during an EAP meeting with input from the school nurse, the parents and carers, myself as the SEN teacher, the teacher assistant, learner services representatives, and others who have an interest in the learner such as the learner's counsellor. The map and its philosophy, purpose, function to SNE, advantages, and limitations were discussed in depth in a previous section (Section 2.4.3.2). Permission was obtained from Perry's organisation to use these maps in this study.

4.5.1.2 The Assessment of Lagging Skills and Unsolved Problems Tool (ALSUP)

Doctor Ross Greene, a Harvard learner psychologist, developed *The Assessment of Lagging Skills and Unsolved Problems Tool (ALSUP)* questionnaire (Greene, 2009, p. 287) to help parents, teachers, and carers who are working with learners who display very challenging types of behaviour such as kicking, screaming, destroying property, and worse. Challenging behaviour typically leads to learners being suspended and becoming disengaged from the school setting over time.

On face value, it may appear that the questionnaire fits with the deficit model. However, the philosophy embedded into the questionnaire is that of a solution-focused model (Section 2.2.4). Greene states that special needs educators have to understand why learners are exhibiting challenging behaviour before they can focus on helping them. His main premise is that learners who display negative characteristics such as being defiant, manipulative, non-compliant, or aggressive are doing so because they are lacking certain skills. Consequently, challenging behaviour occurs when the demands of the environment exceed a learner's capacity to respond adaptively. According to Greene (2009), teachers tend to mislabel the challenging behaviour as "the learner WILL NOT comply", when it is rather a case of "the learner CANNOT comply" (p. 297) because he/she does not have the skills to manage the situation.

In using this model, the first goal is to identify the skills that may be lacking in a learner and the second is to identify the specific conditions in which the behaviours are manifesting. Thereafter, a collaborative problem-solving approach is followed in which the learner assumes the role of the primary agent of change by suggesting potential solutions through empathetic discussions with supportive adults (special needs educators and parents or carers).

In the context of this study, as with the NMT questionnaire, the ALSUP questionnaire is typically completed during EAP meetings. In my own practice, I find it useful as a discussion guide and in establishing common ground between home and school with regards to more challenging behaviours of learners. For example, it leads to discussions on what strategies are in place at home and at school, and how these can be coordinated across both platforms to help the learner manage school. The ALSUP questionnaire is shown in Figure 4.1 below.

Figure 4. 1 ALSUP questionnaire in Likert scale

ASSESSMENT OF LAGGING SKILLS & UNSOLVED PROBLEMS (Rev. 12/5/08)

Child's Name ______________________________ Date__________ Person Completing Form ______________

LAGGING SKILLS

	Never	Sometimes	Often	Always
1. Difficulty handling transitions, shifting from one mindset or task to another	0	1	2	3
2. Difficulty doing things in a logical sequence or prescribed order	0	1	2	3
3. Difficulty persisting on challenging or tedious tasks	0	1	2	3
4. Poor sense of time	0	1	2	3
5. Difficulty reflecting on multiple thoughts or ideas simultaneously	0	1	2	3
6. Difficulty maintaining focus	0	1	2	3
7. Difficulty considering the likely outcomes or consequences of actions (impulsive)	0	1	2	3
8. Difficulty considering a range of solutions to a problem	0	1	2	3
9. Difficulty expressing concerns, needs, or thoughts in words	0	1	2	3
10. Difficulty understanding what is being said	0	1	2	3
11. Difficulty managing emotional response to frustration so as to think rationally	0	1	2	3
12. Chronic irritability and/or anxiety significantly impede capacity for problem-solving or heighten frustration	0	1	2	3
13. Difficulty seeing the "grays"/concrete, literal, black-and-white, thinking	0	1	2	3
14. Difficulty deviating from rules, routine	0	1	2	3
15. Difficulty handling unpredictability, ambiguity, uncertainty, novelty	0	1	2	3
16. Difficulty shifting from original idea, plan, or solution	0	1	2	3
17. Difficulty taking into account situational factors that would suggest the need to adjust a plan of action	0	1	2	3
18. Inflexible, inaccurate interpretations/cognitive distortions or biases (e.g., "Everyone's out to get me," "Nobody likes me," "You always blame me, "It's not fair," "I'm stupid")	0	1	2	3
19. Difficulty attending to or accurately interpreting social cues/poor perception of social nuances	0	1	2	3
20. Difficulty starting conversations, entering groups, connecting with people/lacking other basic social skills	0	1	2	3
21. Difficulty seeking attention in appropriate ways	0	1	2	3
22. Difficulty appreciating how his/her behavior is affecting other people	0	1	2	3
23. Difficulty empathizing with others, appreciating another person's perspective or point of view	0	1	2	3
24. Difficulty appreciating how s/he is coming across or being perceived by others	0	1	2	3

UNSOLVED PROBLEMS

HOME	Never	Sometimes	Often	Always
1. Waking up/getting out of bed in the morning	0	1	2	3
2. Completing morning routine/getting ready for school	0	1	2	3
3. Sensory hypersensitivities	0	1	2	3
4. Starting or completing homework or a particular academic task	0	1	2	3
5. Food quantities/choices/preferences/timing	0	1	2	3
6. Time spent in front of a screen (TV, video games, computer)	0	1	2	3
7. Going to/getting ready for bed at night	0	1	2	3
8. Boredom	0	1	2	3
9. Sibling interactions	0	1	2	3
10. Cleaning room/completing household chores	0	1	2	3
11. Taking medicine	0	1	2	3
12. Riding in car/wearing seatbelt	0	1	2	3

SCHOOL	Never	Sometimes	Often	Always
1. Shifting from one specific task to another (specify)	0	1	2	3
2. Getting started on/completing class assignments (specify)	0	1	2	3
3. Interactions with a particular classmate/teacher (specify)	0	1	2	3
4. Behavior in hallway/at recess/in cafeteria/on school bus/waiting in line (specify)	0	1	2	3
5. Talking at appropriate times	0	1	2	3
6. Academic tasks/demands, e.g., writing assignments (specify)	0	1	2	3
7. Handling disappointment/losing at a game/not coming in first/not being first in line (specify)	0	1	2	3

OTHERS (list)	Never	Sometimes	Often	Always
1.	0	1	2	3
2.	0	1	2	3
3.	0	1	2	3
4.	0	1	2	3

4.6 DESIGNING FOR THE LEARNERS

4.6.1 Design principles taken from theory

The next step was to design a hypothetical learning trajectory (HLT) informed by principles from literature gained and adapted to the needs of the local context. A key point in this regard is that the design of a HLT is multifaceted, with a highly interdimensional nature which increases its complexity (Simonsen *et al.*, 2010). To explain, an HLT involves people, a developing product, a process involving a multitude of activities and procedures, a wide variety of knowledge, tools, and methods, an organisation, as well as a micro- and macro-economic context (Blessing & Chakrabarti, 2009, p. 2). Put differently, the designer works with many components, including a knowledge component, a social component, a cognitive component, often a technical/technological component, and a theoretical component.

With regards to producing a HLT informed by theory, Van den Akker (1999, p. 8-9) remarks on the complex and dynamic role of theory in DBR by describing DBR's relation to theory as theory-related and not theory-driven. As was noted earlier, DBR initiates an ongoing interplay between theory and practice and the consequent role of adjusting both practice and theory progressively. Research and design is integrated so that the research informs the design, and the design then seeks to inform the research, meaning that the output of the one phase becomes the input of the next. Not only is the role between theory and practice interactive and reciprocal, it is also multi-layered. To explain, DBR impacts at a micro-theory level (at the level of instructional activities), on a local instruction theory level (at the level of instructional sequence), on a domain-specific instruction theory level (at the level of pedagogical content knowledge), and on a global theoretical framework level (Nieveen *et al.*, 2006, p. 152).

With regards to producing a HLT adapted to local conditions, it is important to remember that a design object dynamically evolves in relation to its context and specific use. There is also a type of relationship between the teacher-designer and the learners for whom he/she is designing, which engenders an awareness in the researcher of the processes of learning and the support for learning with respect to the learners (Gravemeijer & Cobb, 2006, p. 478). Notably, DBR is not static, meaning that both the components and the relationships may experience change at any point in the course of the design.

Table 4.4 lists general design principles from Task A and Task B, which are used to guide the design of the HLT in this study.

Table 4.4 General principles of design from modelling literature and from disability discourses

NO:	Element of Task Design	Authors
1.	Linked to ACARA	ACARA (2013c)
2.	Assessment: • produce a performance or a product • help teachers decide on future learning needs • contain indicators of accuracy • allow for discussion and feedback	
3.	Challenging, yet accessible, extendable and appropriate: • cater for a range of levels of understanding • experientially real to learners • age appropriate, developmentally appropriate, culturally appropriate • varied to allow all learners to make a start • learners don't have to start and finish at the same place	Ashford-Rowe, Herrington and Brown (2014), Lovitt and Clarke (2011)
4.	Engagement and active involvement in learning: • multimodal • somatosensory in nature • open to a range of methods or approaches	Perry and Pollard (1998) Hall, Meyer and Rose (2012)

5.	Involve learner choice: • autonomy • leads to learner ownership and development • encourage decision-making • flexible • encourage elements of risk-taking	Schalock (2010) Swan (2006) Freudenthal (1971)
6.	Worthwhile mathematical concepts and content: • work towards institutionalised knowledge	Blum (2000) Blomhøj and Jensen (2003)
7.	Bridges/Transfers: • help learners make sense of the real world • build connections between important academic concepts • be generalizable • establish meaning	Sekerák (2010) Streefland (1991) Van den Heuvel-Panhuizen (2000)
8.	Build higher-order cognitive processes: • provoke cognitive dissonance • Feuerstein's cognitive operations • critical reflection • metacognition	Feuerstein *et al.* (2010)
9.	Collaboration: • may have to start parallel • shared decision-making • communication	Perry and Pollard (1998) Black-Hawkins (2014)
10	Rhythm: There must be a change in activities to keep learners involved (rhythm of activities); a change in movement so that learners do not just sit behind their desks (rhythm of movement); a change in how the teacher uses voice to address learners (rhythm of sound); and so on	Perry and Pollard (1998)

Table 4.4

4.6.2 Design principles informed by the school itself

Our choice of topic was determined by the school's schedule of instructional material. Clearance was obtained from the various stakeholders (school, ethics committees, and parents) to conduct the research as part of the learners' daily mathematical classes. Based on the *Visible Learning* drive, all staff in the special needs centre have to run the same learning strands and mathematical topics at the same time for a predetermined period as part of the collaborative planning directives. At the time, the special needs unit of the school was working on the areas of *Shape and Location,* which I then adopted as context for the activities. The original intent was to work with *Numbering and Patterning,* but this was the learning theme in Term 1, and the school gave permission for the research to take place in Term 2.

The theme of the learning relates to location, and learners would study location through a mathematical modelling approach. Their materials would need to be somatosensory in nature. The ideal was for them to learn in the context of a small group setting. The teacher would fulfil the role of mediator between the learners, the content, and their thinking processes. The mathematical lessons would take place at school and would follow their usual timetable. The goals and the assessment standards were also taken from ACARA (ACARA, 2013c).

4.6.3 Designing the instructional activities

This part of the research relates to Task D, where Task D is as follows:

Task D: Designing a hypothetical learning trajectory (HLT)

Task D relates back to the following secondary research question: *How does the learners' learning correspond with the proposed learning trajectory?*

For the most part, the content of the HLT were derived from the descriptors located under the *Location and Transformation* strand of ACARA. A key point to remember is that the design of the HLT is also a learning process and is best described as a design-in-the-making. This means that the design in DBR is never final, as it is in traditional research. It is an ongoing process of introducing alterations and examining the impact of those alterations on learning. Collins *et al.* (2004) adopt the term "progressive refinements" (p. 19) from the Japanese car industry to describe the series of approximations towards improvement.

4.6.3.1 Challenge 1: Easter Egg Hunt

The Easter Egg Hunt was the first of the modelling tasks given to the learners. The learners were informed that we would be holding an Easter Egg Hunt on the last day of school that week, which fell on a Thursday, to celebrate the Easter long weekend starting that Friday. Accordingly, learners had to work in groups, decide on a secret location, and then develop a set of directions that would serve as cues for the other groups searching for the treasure. In terms of ACARA, the task was matched to the Foundation and Year 1 level descriptors under *Location and Transformation.* In accordance with the descriptors, learners needed to describe position and movement as well as give and follow directions. At Foundation Phase level, the learners should be able to interpret everyday language such as "between", "near", "next to", "forwards", "towards", and be able to give simple directions as would be needed for sending someone around an obstacle course. Comparatively, the Year 1 specifications require that the learners understand that people need to give and follow directions to and from a place, and that this involves turns, direction, and distance.

4.6.3.2 Challenge 2: Defuse the Bomb

This challenge continued along the ACARA theme of *Location and Transformation*, with more emphasis given to Year 1 descriptors of giving and following directions with respect to turns and clockwise and anticlockwise parameters. With this in mind, learners were given a "bomb" and asked to "defuse" it by working out the combination of the three-step lock. The exact steps required were to defuse the bomb, produce the combination lock's code, which included working out the numbers on the dial, the number of turns to get to the numbers and the direction of turns, and thereafter to give their code to the other team for verification. The design of the bomb can be found on the following website: (http://www.instructables.com/id/How-to-Build-a-Cardboard-Combination-Padlock).

4.6.3.3 Challenge 3: Destination Grid Map and Helicopter Flight

The objective of this task was to create a top view diagram of the school, then to overlay it with a self-designed grid map, and thereafter to give the directions to specific destinations around the school using the grid map and its co-ordinates as a reference system. It was taken from Year 3 descriptors. The task was broken down into several sub-tasks:

Subtask 1: Build a physical model from foam blocks that represents a top view of the school as seen from *Google Earth.*

Subtask 2: Draw a 3D shape on dot paper.

Subtask 3: Understand how to derive and draw a top view from a 3D shape. Draw a top view of the school as seen from *Google Earth*.

Subtask 4: Choose one top view drawing from amongst all the drawings made, which will be the blueprint for the grid reference.

Subtask 5: Design a grid reference system. Use it to overlay the top view of the school.

Provide the other team with grid references to fly a remote-controlled toy helicopter to the spot marked by the coordinates.

4.6.4 A Hypothetical Learning Trajectory

Table 4.5 provides a summary of the features of HLT with respect to the goals in

ACARA.

Table 4.5 The localised Hypothetical Learning Trajectory used in this study

Features of modelling task	**Challenge 1: Easter Egg Hunt**	**Challenge 2: Defuse the Bomb**	**Challenge 3: Destination Grid Map and Helicopter Flight**
Description of Challenge	Decide on a suitable location for a treasure at school or in town. Create directions to the treasure for another group to follow. Follow directions to find another group's treasure.	Defuse the bomb by working out the code. The code must contain the numbers on the dial, the direction and amount of turns to get to the numbers. Give the code to the other group to see if they can defuse the bomb with the code provided.	Create a top view map of the school. Overlay it with a grid reference system. Use coordinates to show key positions around the school. Give the grid reference system and coordinates to the other team. Second team flies a remote-controlled toy helicopter to the location of the coordinates provided by the first team.
Position in ACARA	Foundation (ACMMG010) "forwards, backwards…" Year 1 (ACMMG023) "left, right…"	Year1 (ACMMG023) "clockwise, anticlockwise" Year 2 (ACMMG046) "¼ turn and ½ turn"	Year 3 (ACMMG065) "Simple grid reference system"
Broad goals	Give and follow directions to familiar places. Include turns, direction, and distance.	Understand that people need to give and follow directions to and from a place, and that this involves turns, direction, and distance.	Use a grid reference system to describe locations. Describe routes, using landmarks and directional language.

Specific learning objectives	Use directional words and phrases. Interpreting the everyday language of location and direction, such as "between", "near", "next to", "forwards", "towards".	Understanding the meaning and importance of words such as "clockwise", "anticlockwise", "forward", and "under" when giving and following directions. Combine it with distance (how many turns). Identify and describe half and quarter turns.	Comparing aerial views with maps with grid references. Creating a grid reference system for the classroom and using it to locate objects and describe routes from one object to another.
Mathematical tools	Basic maps		Basic grid reference systems
Anticipated level of familiarity	Context: High Content: High Learners are familiar with the school and the town. They are familiar with giving and following directions. Gave directions to one another around an obstacle course the year before.	Context: Low Content: Medium to Low Unsure how familiar learners were with using a combination lock. Learners had some familiarity with clockwise and anticlockwise (completed a section of telling the time the term before). Unsure how familiar learners were with basic fractions e.g. whole vs ½ vs ¼ turn - again some relation to telling the time the previous term.	Context: Medium to High Content: Medium Unsure how familiar learners were with grid maps. Unsure if they were familiar with deriving views (top view) from a 3D model.

Feuerstein's cognitive operations (written in the positive)	**Elaboration Phase:** • Search for relevant cues. • Spontaneous need to compare. • Recall and use several pieces of information, including information from long-term memory. • Use logical evidence. • Abstract thinking, visualise. • Develop problem-solving strategies • Make a plan - think forward.	**Input Phase:** • Focus and perceive. • Systematically search for a solution. • Use labels. • Know where you are in space (left, right). • Be aware of time (how much, how often, sequence of events). • Conserve constancies. • Collect precise and accurate data. • Use more than one source of information.	**Output Phase:** • Consider another person's point of view. • Project virtual relationships (can see things that aren't there). • Stick to it, perseverance. • Take time to think (avoid trial and error responses). • Give a thoughtfully worded response. • Use precision and accuracy. • Visual transporting (copy accurately from a source). • Show self-control.
Resources	*Google Earth* "Treasure"	"The bomb" - combination lock made out of cardboard.	*Google Earth* Remote-controlled toy helicopter.
Multimodal Somatosensory Rhythm	Visual (*Google Earth*). Movement around school (running to find the treasure).	Tactile (turning knobs and watching rotators move).	Visual (*Google Earth*). Flying a remote-controlled toy helicopter.

Table 4.5

4.7 SEEKING EXTERNAL FEEDBACK ON THE TASKS

The next step in the design process was to evaluate the HLT in collaboration with others before the implementation phase.

Task E: Pre-Evaluation:

Screening, Co-Teaching and Tryout of Approach (not activities), Practitioner

Consultation, Consultation with Cultural Advisor, Expert Consultation

4.7.1 The need for external feedback

Researchers of DBR need to collaborate with others as they identify and explore a significant educational problem (Herrington *et al.*, 2010, p. 3997-4015 Kindle edition). To explain, the researcher may have to work with cultural advisors to gain an insider perspective and work with participants to gain their trust. Furthermore, the researcher has to subject his/her work and thinking to other experts and use their professional scrutiny to control for subjective biases and interpretations. Typically, this collaboration process requires adaptation, communication, coordination, and organisational skill on the part of the researcher. A key point is that connecting with other people over the research also implies adopting several roles in relation to different people who are involved in the study. For example, the researcher has to participate in roles such as designer, advisor, facilitator, observer, outsider and insider, and in this study, teacher.

4.7.2 Interviewing collaborators

I asked several people representing different agencies with diverse but compatible social objectives to consult with me on the instructional design. Their input was necessary to help me maintain a more critical perspective towards the design by buffering my own subjectivity and by creating some form of intellectual distance between me and my efforts. These consultations were prescheduled. During the consultations, the key topic of conversation concerned the suitability of the tasks in relation to the learners' worlds — their challenges, culture, development, and any other factors relevant to their learning. The nature of the interview matched an interview guide approach with pre-determined topics (Patton, 2003, p. 12) yet assumed a conversational style where we shared ideas and reacted to each other's observations and remarks. The interviews typically ranged between 60 and 90 minutes in length. In Table 4.6, I compared Patton's (2003, p. 12) and Merriam's (2009, p. 89) demarcation of structure of qualitative interviews ranging on a continuum from open and flexible to rigid and fixed. Accordingly, I show on this table that the type of interviews with collaborators were semi-structured in nature.

Table 4.6 Interview structure continuum showing the type of interview used in this study

Interview structure continuum				
Description	No predetermined questions Questions emerge spontaneously from the immediate context	Topics and issues determined in advance Wording and sequencing of questions adjusted as interview unfolds	Exact questions decided in advance Ask using exact wording in exact order	Questions and response categories decided in advance Response categories fixed. Respondent chooses a category from given list
Key characteristics	Open and exploratory	Flexible	Fixed	Fixed
Patton (2003)	Informal conversational interview	Interview guide approach	Standardised open interview	Closed quantitative interview
Merriam (2009)	Unstructured or informal	Semi-structured	Highly structured.	

Table 4.6

Moreover, Patton (2003, p. 8) states that there are six different types of knowledge that can be elicited with interview questions. In Table 4.7, I list the three main questions I asked the collaborators and show how I depended on all six types of knowledge as per Patton's definition.

Table 4.7 Types of knowledge elicited from collaborators

Interview question	**Questions asked of collaborators:**

knowledge options (Patton, 2003)	• How suitable are these tasks to the learners in their context? • What are the pitfalls or difficulties you foresee? • How can the tasks be improved/refined?
Behaviours or Experiences	Interviewees were selected because of their background and experiences around disability practices, local school practices, and community practices.
Knowledge	I wanted to incorporate their knowledge into the design so that the learners could benefit from their expertise.
Sensory	I co-taught with one member and was observed by the cultural advisor so they could see how I taught.
Background	Their background represented three different knowledge systems: ● Inclusive practices from Britain (co-teacher) and Australia ● Inclusive practices from America (disability advisor) and Australia ● Inclusive practices from an Indigenous perspective (elder from community) All three individuals were involved in the school through their work roles and thereby familiar with the learners and the school itself.
Opinions or Values	I wanted to know if the design was age-appropriate, developmentally appropriate, culturally appropriate, and appropriate from a local school perspective, a broader disability perspective, and a cultural aspect. Their opinion could help me create a design that was developmentally appropriate, age-appropriate, and culturally appropriate.

Table 4.7

4.7.2 The types of external feedback used in this study

In Table 4.8, I provide a summary of who the collaborators were and their input into the design.

Table 4.8 Sources for evaluation of the design prototype and their input into the design

Source	**Person**	**Purpose**	**Specific Focus**
Screening	Myself	Audit of classroom activities against literature, own professional experience, and knowledge of the learners	Was I as a teacher-designer satisfied with the product when looking at it through the lens of design principles from literature and practice
Co-Teaching	Team leader of SEN division. 30 years international teaching experience in SEN classrooms	"Critical friend"	Instructional match Social dynamics of learners
Practitioner consultation	Same teacher with whom I co-taught	Evaluated proposal and instruments against school's expectations	Alignment to school's practices around *Visible Learning*
Expert review	Disability Advisor from Student Services	Suitability of the task for learners with SEN	Multimodal (representation) Use of higher-order cognitive processes (Webb's (1997) DOK levels) Use integrated approach with tasks and other parts of the curriculum
Cultural advisor	An elder from the Indigenous community	To ensure sensitivity to cultural practices	Classroom setup Integrating boys and girls into the same group Whether any of the activities offended the cultural views

Table 4.8

Based on the input from the collaborators, the observation instruments were adjusted to reflect more of the philosophy of *Visible Learning* (Hattie, 2009) by way of aligning the research with the school's practice. In addition, the Webb DOK levels matrix was introduced to make sure that the higher order cognitive processes were developed and assessed. A multimodal approached was encouraged, such as found in *Universal Design for Learning* (the tasks had to be represented in different ways, and learners should be allowed to express themselves in a variety of ways to show their knowledge). Last, the cultural advisor's role was discussed and developed with her.

4.7.3 The role of the cultural advisor in the study

I invited the school's community liaison at the time to be my cultural advisor. We agreed that she would visit my class, talk to the learners, watch me teach, and look over my designs. She was suitable as a cultural advisor as she was an elder of her Indigenous people. Furthermore, she was suitable as an intermediary between the learners and myself since she was known to the learners, accessible to them in so far as she worked at the school, and more importantly, she was approachable to the learners in that the learners seemed to like her and feel comfortable around her. In Table 4.9, I outline the role she played in assisting me as the researcher-designer-teacher, and the role she played with the learners as their intermediary and advocate.

Table 4.9 Role of the cultural advisor in this study

Role of cultural advisor in supporting me as the teacher:	**Role of cultural advisor in supporting the learners:**
Cultural advisor	Intermediary and advocate
Support the teacher-researcher	Support the learners
Evaluate lesson plans from a cultural perspective	Act as mediator - invite learners to participate in the research

Role of cultural advisor in supporting me as the teacher:	**Role of cultural advisor in supporting the learners:**
Observe teaching and classroom arrangement Before the research: 2 occasions During the research: 1 occasion	Visit class to establish familiarity with the learners and to check on their well-being Before the research: 1 occasion During the research: 1 occasion On both occasions, she spent time with the class as a group, but also pulled the learners out of the class individually to check on their well-being. During her second visit she checked whether the learners who were in the research encountered any personal difficulties with the research, and if they wanted to continue or opt out as participants in the study.
	Was available at school for learners to consult with if needed

Table 4.9

4.8 IMPLEMENTING THE ACTIVITIES IN THE CLASSROOM

After I created the designs, and evaluated them with others, it was time to implement them into the classroom. This part of the study relates to:

Task F: The implementation of three modelling tasks in a SEN classroom.

There were three secondary research questions attached to Task F, namely:

- *How do the learners' characteristics, taken from their psycho-educational profiles, affect their modelling?*
- *How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?*
- *What evidence of learning could be found in the analysis of learners' reasoning and representations over time?*

4.8.1 How data were collected in the classroom

Previously in this chapter, I explained that I assumed the role of teacher-researcher and gave my reasons for this choice, and potential side-effects to the study. I show in Figure 4.2 that according to Gold's (1958) seminal classification, I fulfilled the role of a participant as observer.

Figure 4. 2 Teacher-Researcher's role in the field

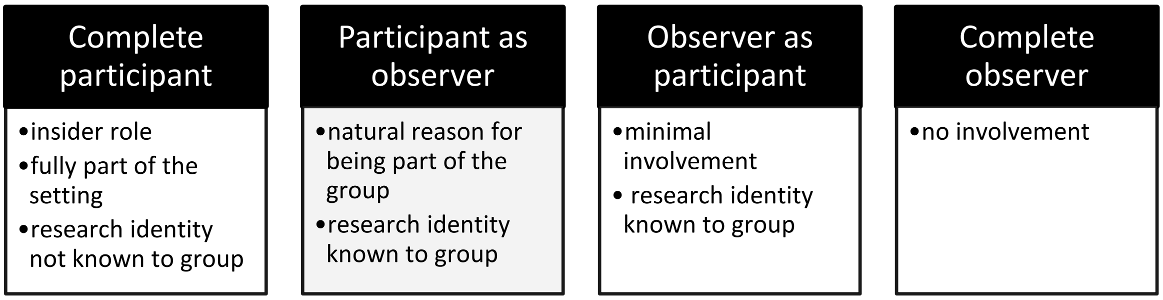


Figure 4.2

4.8.2 A discussion of the data collection methods used

In this part of the study, data are needed on the design "in use". As was noted before, it was an emergent design being used in a naturalistic setting in a classroom. For this reason, a more holistic perspective would relay the interdependent complexities playing out between the design and its users and their effect on the evolution of the approach. Who were the learners? How did they respond to the approach? How did the designer respond to the learners' responses? What modifications were made to the design and why? In reality, the sum of the approach is clearly more than its individual parts and therefore the whole of the instructional programme needed to be evaluated. Consequently, I chose to answer the research questions through a qualitative evaluation and used the checklist provided by Patton (2002), accordingly.

Another reason for preferring a qualitative evaluation over a quantitative one had to do with the issue of learning. All things considered, that is, the lack of literature and practice on the subject of modelling as an instructional approach for learners with SEN and how different the modelling approach is to the typical method of direct instruction, it would be premature to test or measure learning from the outset. For the sake of science, it is important to take a step back and first establish whether learning does indeed occur in a modelling setting. Once we have some evidence of learning, it creates confidence to measure and test the learning thereafter, by effect size comparisons, for example.

And lastly, from a disability standpoint it is important for the study to include a voice perspective. It supports the disability ideals of "nothing about us without us". Patton (2003) states that "qualitative methods in evaluations tell the programme's story, by capturing and communicating the participants' story" (p. 2). At the same time, the participants' story illuminates the processes and outcomes of the programme for designers and practitioners.

On the other hand, there are real challenges with DBR and data in a classroom setting. For example, Kelly (2003) describes the educational system "as open, complex, nonlinear, organic, historical, and social" (p. 3). Likewise, Collins, Joseph and Bielaczyc (2004, p. 16) mention that classrooms are messy with too many variables that cannot always be experimentally controlled. A mere glance at these descriptions is enough to bring home the intricacy of the education system. DBR is transparent in its acknowledgement of the entanglement of the various parts of the system. Yet, there is the understanding that for DBR to capture learning in situ (Brown, 1992, p. 152) and to develop educational solutions or innovations that are both use-inspired and robust, one should endeavour to push through the motleyness instead of trying to sidestep it altogether or to artificially demarcate it into neat little boxes of experimentation. At the same time, the confoundedness of doing research under such conditions, in particular the labyrinthine network of impacting variables, is not easy to explain or to explain away. For example, practical challenges of DBR include that real-life settings produce very large quantities of data (Collins *et al*., 2004, p. 16). Moreover, researchers may also attempt to crossover into areas with which they are unfamiliar and end up producing data that are useless or biased because they have little experience with the underlying paradigms within these areas (Blessing & Chakrabarti, 2009).

4.8.2.1 Qualitative data collection techniques

Patton (2003, p. 2) explains that there are three types of data collection methods in a qualitative analysis, namely, interviews, observations, and documents. Likewise, Kelly (2006) notes that data collection in design research typically takes the form of analysis video recordings of the actual learning occurrences, as well as collecting samples of the learners' work and, in some instances, clinical interviews or tutorial sessions. The use of documents in the study was discussed earlier in this chapter with respect to drawing up psycho-educational profiles of the learners, from their school files. I explained that this process was necessary to "get to know" the learners' strengths and weakness so I could design and plan for these. Furthermore, during the implementation phase it was important to analyse how their characteristics affected their learning and, consequently, the effectiveness of the modelling design. In this part of the study, the use of documents refers to samples of the learners' work. In Table 4.10, I explain how three types of qualitative data collection methods were used in this study.

Table 4.10 A list of data collection methods during the implementation phase of the study

CData collection (Patton, 2003)	**Instrument**	**Purpose**
Observation	Field Notes guidelines	To describe what people in the class did at a given time or over a period of time, with a specific focus on how the learners engaged with the modelling cycles and with collaborative learning demands.

CData collection (Patton, 2003)	**Instrument**	**Purpose**
	Video Analysis Audio-recordings (back-up)	To provide a detailed scrutiny of events, with a specific focus on how the learners were supported (mediation). Clips will also be shown and shared with the participants as part of their pastoral care lessons on becoming a better learner.
Interviews with learners	Individual questions (Questions during the implementation of a challenge)	To make the learners' implicit thinking explicit at a given time. To understand their mathematical reasoning from their own perspectives.
	Focus group interview (Questions after the implementations of a challenge)	To give the learners a voice. To understand the study from their perspective. To capture the experiences from the learners' perspectives and to gain insight into the meaning they assigned to modelling. To capture the learners' own views on how modelling influenced their learning.
Interview with LSA	Conversational interview	To gain another perspective on the day's activities. To find out if anything happened that I might have missed while teaching that was relevant to the study.
Collecting evidence of learning	Samples of learners' work	To assess the learners' mathematical knowledge on the topic. To assess the learners' cognitive functions.

Table 4.10

4.8.2.2 Observation / field note guidelines

Table 4.11 contains the field note observation guidelines I used during the study, and their purpose in the study. I loosely structured the list of questions in relation to the modelling phases of the learners followed in this study, their knowledge processes, their social process, their like or dislike of the modelling process, and possible future interventions.

Table 4.11 Field observation guidelines

CATEGORY	QUESTIONS	RATIONALE
Learning Intentions of Task	What were the learning intentions? What evidence is there that the learner achieved the objectives?	Assessment against ACARA
Identification phase (Modelling Phase 1)		
Cognitive dissonance	Did the learner experience cognitive dissonance? What was the response to cognitive dissonance? Did he/she recognise it, accept it, and initiate activities to address it?	Could learners specify the problem?
Owning the problem	Willingness to invest effort (concentration, perseverance)	Willingness to pursue the problem (Evaluate buy-in from the learner)
	Goals set	Assess ability of learner to extract clues from the information and translate them into a clear expression of the problem to be solved
Construction of the mathematical model (Modelling Phase 2)		

Data Collection	What did the learner focus on? In what ways did he/she focus? When did the learner sustain focus (and lose it)? What questions did the learner ask?	Assess ability of learner to determine important factors in solving the problem
Organisation	How did the learner try and organise information? How did the learner try to connect diverse ideas? How did the learner try to use the information to assist in his/her planning?	Assess ability of learner to develop relationships between the important factors
Use of mathematical strategies and/or cues	Strategies for problem-solving	Assess ability of learner to use strategies towards solving the problem
	Strategies for error detection	Assess ability of learner to evaluate the model
	Response to cues	
Verification of the model: (Modelling Phase 3)		
	Information used	Assess learner's depth of knowledge (deep or surface)
	Explanations given	
	Errors (what was wrong and why)	Assess ability of learner to evaluate the model
	Learners response to: - Where am I going? - How am I going? - Where to next?	To gain insight into the learner's thinking and reasoning processes
	How did the learner communicate ideas?	
	Relationships with other parts of the task	Assess quality of learner's knowledge Deep or surface learning?
	Relationships with other ideas	
	Understanding of concepts/knowledge related to the task	
	What new information did the learner generate?	

	Did the learner attempt to generalise the information to a new setting?	
Participation/Engagement		
Collaborative learning processes	Seeking help for further information/and or to confirm a response	Evaluate learner's ability to learn with and from peers
	Seeking and dealing with feedback	
	Ability to peer assess against criteria and give feedback based on criteria	
	Ability to review own and others' work	
	An evaluation of learner's social skills	
Affect, Emotion, Attitude	How did the task affect the learner's motivation or emotional state?	Monitor enjoyment and satisfaction level of the learner
Reflection as a teacher	What is surprising about their learning?	Assist in future planning Assist in modification of learning design Start looking for general design principles
	What have the lessons made me think about?	
	What gaps did I observe? What strategies are needed to close the gap?	
	What are my future actions?	

Table 4.11

4.8.2.3 Video analysis and audio-recordings

Whereas the observational guideline is weighted towards a more general impression of the "learner-modelling task" and "learner-peer collaboration" types of interactions, the use of video analysis in the study allowed for repeated analysis and detailed scrutiny of classroom events. For this reason, I used the video material to:

- Analyse the relation between modelling and the learners' cognitive functions in terms of Feuerstein's theory. Specifically, how these cognitive functions manifested in relation to the task, how they were mediated, and how they affected the learners' representations.
- Analyse the relation between the learners' psycho-educational profiles and their learning. For example, to examine what strengths and vulnerabilities the learners displayed during the modelling tasks and how these affected their mathematical performance at the time?
- Analyse and provide detailed descriptions of the support that was given to the learner.
- Serve as a back-up to the field notes in analysing the behaviours and dynamics in the classroom during the modelling tasks. Video analysis in the study helped me by widening the scope of what I could "see" as researcher, in comparison to what I could "see" as teacher. To explain, as a teacher on the ground it is easy to get locked into a learner or a particular teaching-learning situation at a given moment, and thereby remain unaware of concurrent developments happening on the outskirts. The video data helped me to shift my perspective to that of a researcher by observing from the side so to speak, as I could replay frames and shift my attention around to incorporate and examine a range of dynamics. The ethical issues around the use of video recordings in the class and how these were addressed are discussed at a later stage in this chapter.

4.8.2.4 Interviews with learners

Patton (2002) discusses the rationale behind interview questions:

> We interview people to find out from them those things we cannot directly observe. The issue is not whether observational data are more desirable, valid or meaningful than self-report data. The fact of the matter is that we cannot observe everything. We cannot observe feelings thoughts and intentions. We cannot observe behaviours that took place at some previous point in time. We cannot observe situations that preclude the presence of an observer. We cannot

> observe how people have organised the world and the meanings they attach to what goes on in the world. We have to ask people questions about those things. (p. 340)

Likewise, King and Horrocks (2010, p. 26) support the idea that interviewing is a tool with which to get to people's perceptions, experiences, and opinions.

In light of these authors' statements, I used the method of interviewing the learners to explore the meaning the learners assigned to the modelling experience. Specifically, my intention was to draw out two different types of responses from the learners. The first type of response was related to the outcomes of the design. Did the learners perceive the modelling tasks to be helpful or hindering with respect to their learning of mathematics? In other words, I wanted to know from the learners if and how outcomes of mathematical learning were attained. The second was related to what the modelling meant to the learners. How did they feel about learning this way? What was their opinion of the design as an approach to mathematical instruction? The interview schedule used with the learners and its intended purpose during the focus group session is found in Table 4.12

Table 4.12 Interview questions for learners in focus group setting

<table>
<tr><th>Questions asked</th><th>Types of questions asked of learners (Patton, 2003)</th><th>Purpose of the question</th></tr>
<tr><td>When were you learning?</td><td>Experience of the learner</td><td rowspan="4">The objectives of these questions was to hear the learners' side of how the modelling activities were (or were not) helping them to learn mathematics.

It was meant to uncover their view (meaning, opinion, feelings) of the HLT and the consequent learning</td></tr>
<tr><td>When were you not learning?</td><td>Experience of the learner</td></tr>
<tr><td>What did you learn?</td><td>Knowledge of the learner</td></tr>
<tr><td>What do you want us to change so that you can learn even more?</td><td>Knowledge and experience of the learner</td></tr>
</table>

Questions asked	**Types of questions asked of learners (Patton, 2003)**	**Purpose of the question**
How do you feel about these activities as a way of learning?	Opinion and feelings of the learner	experiences which were derived from its use.
How do you feel about working in groups as a way of learning?	Opinion and feelings of the learner	

Table 4.12

As per the Students Services Disability Advisor's request to make use of an integrated curricular approach where possible, the learner interviews were integrated into the *Pastoral Care* lessons of the school. The school's *Pastoral Care* curriculum for the term was taken from the *Visible Learning* programme, and was meant to cover topics such as "Learning in groups" and "What it means to be a good learner?". For this reason, the timing of the research was a good fit with the school's planning. There were three phases to the learner interviews as part of their *Pastoral Care* lesson. First, learners were shown video clips from the modelling activities of the previous week. Whereas some video clips were random, others were chosen for the purpose of showing both positive and less positive aspects of the class dynamics which emerged during the modelling tasks. Second, learners were asked the interview questions in a whole class manner, which gave them the option to comment or not to comment without additional pressure. Third, learners became part of a group discussion on how we as a class were doing in terms of learning together and how we were meeting the criteria for good learners as per the school's programme.

4.8.3 Seeking collaboration

During the implementation phase, I collaborated with four other parties who again acted as critical friends and who gave me feedback on my ideas, practice, and challenges. The cultural advisor and my SEN colleague were the same two people who I collaborated with during the pre-evaluation phase of the HLT. To get input from a mathematical perspective, I invited the team leader of the school's mathematics department to be my critical friend. In between each new mathematical challenge, on the weekends, I met with the SEN colleague (Week 1) and the mathematics colleague (Week 2). Ideally, it would have been more valuable to meet with both parties together in a type of panel format, but their personal circumstances prevented such a meeting. The interview with these collaborators followed the format of an informal conversational interview in that it was largely unstructured (Section 4.7.2). Topics were related to challenges that emerged from the research that week and general topics of discussion included what the *learning* of mathematics really means, what counts as evidence of learning during open-ended problem solving tasks, suitable task designs for learners with SEN, and how to create a group dynamic conducive to mathematical problem solving. Typically the appointments were three hours long (an afternoon session).

Moreover, during the time of the research a professor in mathematics education at an Australian university visited the school to conduct an in-service training on teaching mathematical problem-solving to learners. Only mainstream teachers attended the professional development session, yet the professor was kind enough to schedule me an hour appointment to discuss matters around the learning of mathematical problem-solving from the perspective of my research. To protect the anonymity and confidentiality of the learners, we tried to maintain discussion on a general perspective of teaching and learning as well as from my perspective as a teacher of a SEN class, thereby intentionally bypassing references to specific learners involved in the study. Since most of the collaborators were familiar with the school and with my own practices, they were able to evaluate my challenges accordingly without me having to divulge any additional details with regards to the learners.

Table 4.13 Sources of collaboration during the implementation phase

SOURCE	PURPOSE	TYPE OF INTERVIEW SCHEDULE
Cultural Advisor	To monitor well-being of learners and their decision to continue with the research	Informal conversational interview Unstructured Topics were related to challenges that emerged from the research that week.
Practitioner Consultation: SEN Team leader: Mathematics Team Leader:	Critical friend, advisor, and sounding board on learning situations that emerged during the research	
Expert Consultation: Visiting professor of mathematics education conducting in-service training on problem-solving	Consultation on issues related to problem-solving and learning	

4.8.4 The time frame for the intervention

The purpose of the challenges was to progress incrementally through the mathematical strand of *Location and Transformation*, and aspects of *Shape* were incorporated into the study as well.

A key point in the study is that I intentionally planned for the activities to take place in the classroom in between a series of long weekends. This was done for two reasons. First, it gave me as the researcher-designer more time than usual between the cycles to analyse the activities, to seek collaboration on issues that emerged during that cycle, and to reflect on and make the necessary amendments before the start of the next cycle in the form of a new mathematics challenge for the learners.

Second, it was meant to protect the well-being of the learners should they find the change in routine stressful. To explain, the calendar breaks gave the learners extended "downtime" at home. Moreover, it is a local tradition that families get together over these long weekends, for example, by going camping or for members from more remote communities to come into town to spend time with their families, and the town's people going "out bush" for the same reason. Positive family get-togethers could potentially enhance the learners' social-emotional well-being, thereby lessening the impact of any unforeseen levels of stress from the research on the learners.

That is to say, I tried to put into practice in the study the recommendations of Feuerstein *et al.* (1988):

> Individuals must learn that by becoming modified they will have to assume different roles according to situations presented... The mediator, aware of these changes, will help the student to anticipate the stress and will ensure that there is support and feedback for him at every step of the process, to make it possible for him to cope... Change and awareness of being modified is certainly a source of stress but need not become a source of distress. (p. 84)

On the negative side, some of the learners missed class as they either left early or stayed late on their camping excursions with their families.

Table 4.14 and Table 4.15 depict the actual implementation timeline of the study. Whereas Table 4.14 refers to the first two weeks of the study, and covers the *Easter Egg Hunt* (Week 1) and the *Defuse the Bomb Challenge* (Week 2), Table 4.15 covers the last two weeks of the study (Week 3 and 4) and refers to the *Fly the Helicopter Challenge*. These tables describe various aspects of the implementation phase in relation to the timeline. First, they show the different roles I adopted, where the blue demarcations show that my role as teacher received more attention and the orange areas show that my role as designer-researcher was emphasised. Moreover, these tables make a distinction between the intended developments, meaning the activity planned in the HLT, and the actual developments, that is, what happened in the classroom on that day. In this regard, blue areas indicate where the intended and actual aspects of the HLT merged together as originally planned, whereas the purple areas show activities that were not part of the original HLT, but that developed as the study progressed, and were subsequently blended into the research. The red writing shows when the student focus group interviews took place.

Table 4.14 Actual implementation timeline of the study – Week 1 and 2

Mon	**Tues**	**Weds**	**Thurs**	**Fri**	**Sat**	**Sun**
Week 1	**Teacher – Easter Egg Hunt Challenge**			**Easter weekend: Designer-Researcher**		
Problem identification: Virtual or school based hunt	Model construction: Treasure spot	Model construction (refinement): Develop and check directions	Model verification: Follow the directions to the treasure	• Watch clips • Read field notes • Collate representations • Backup material • Collaborative reflection with SEN practitioner		
Week 2	**Teacher – Defuse the Bomb Challenge**			**ANZAC weekend: Designer-Researcher**		
Planning of next cycle Adjustments from previous cycle	Problem identification and model construction Find code Learner focus group	Model construction (refinement) Develop code	Model verification Follow the code to defuse the bomb	• Watch clips • Read field notes • Collate representations • Backup material • Collaborative reflection with Mathematics practitioner		

Table 4.14

Table 4.15 Actual implementation timeline of the study – Week 3 and 4

Mon	**Tues**	**Weds**	**Thurs**	**Fri**	**Sat**	**Sun**
Week 3	**Teacher – Fly the Helicopter Challenge (Top View)**				**May day weekend**	
Problem identification : Construct top view with blocks	Problem identification : Draw 3D shape Learner focus group	Model construction (refinement): Draw top view	Minecraft (filler) while learners print and prepare drawings	Model verification Choose best top view drawing and justify choice against criteria	• Watch clips • Read field notes • Collate representations • Backup material	
Cultural advisor visits class, follows up with learners	Visiting professor					

Week 4	Teacher: Fly the Helicopter Challenge (Scale, map and design grid reference)				
	Problem identification and model construction: Decide on scale and map it on the oval Learners began measuring Learner focus group	Problem identification and model construction: Decide on scale and map it on the oval	Model construction (refinement) Adjust scale to inside parameters Model verification Does scale fit?	Problem identification: Design a grid reference Model construction Grid reference Model verification: Fly the helicopter to the coordinates	Analyse data and prepare for publication Inform parents of results once study is finalised Submit reports to organisations with an interest in the study (Ethical committees, university, Department of Education)

Table 4.15

4.9 VALIDITY, CREDIBILITY AND RELIABILITY ISSUES IN DBR

Historically, the nature of research has been changing. Hoover, Hole and Kelly (2000) note how the shifts in the meaning of validity, credibility, and reliability have changed the roles of the researcher and of the learner. In the past, research credibility demanded the researcher to remain detached and objective while being the expert, the learner was generally considered as passive and studied in isolation as an individual, there was a strong emphasis on cause and effect inferences or correlation measures to ensure validity, and reliability was concerned with reproducing results, and validity entailed correlations to standardised tests.

In contrast, today the roles of the researcher and learner are very different. To illustrate, there is ongoing recognition that learners construct their own content and attribute their own sense of meaning to situations that may be very different to those intended by the researcher. Moreover, the relevance of data are no longer determined only by once-off periodic testing such as pre- and post-test measurements based on average. Using numbers to interpret human performance has been exchanged with thick ethnographic descriptions attained through ongoing cycles of observation. There is also a deeper recognition that the interpretation of phenomena are shaped by the cultural and social biases of the researcher. For this reason, the researcher is recognised as both a participant and an observer; as a co-constructor of knowledge with the participant; as learner-listener who values the views and perspectives of the research subjects; and, who engages continuously in self-reflexivity. Correspondingly, a very detailed and philosophical analysis of Lesh *et al.*'s account is articulated in Lincoln, Lynham and Guba (2011, p. 97-129).

In the final analysis, Lesh *et al.* (2000) use the metaphor of a defence lawyer to describe the new role of a researcher:

> The role of the researcher is less like that of a detached and disinterested judge, and more like that of an excellent defence lawyer who knows an area of study well, who cares deeply about it, but who nonetheless has the responsibility to present a case fairly, using evidence and lines of argument that are auditable and credible to a sceptic. (p. 27)

That is, for authors such as Lesh *et al.* research is therefore also about presenting a chain of reasoning around clear assumptions, relevant data, and results related to a specific purpose. It is about developing a coherent and persuasive argument that can be shared and audited by others, including sceptics. The argument must be meaningful and useful. It must reveal and illuminate relevant issues with sufficient detail in an internally consistent manner.

Although I appreciate accounts such as Lesh *et al.*'s, I am concerned that the roles of researcher and learner may revert back to more traditional practices through the push of evidence-based practices (Section 2.5.2.2) in schools.

Nieveen and Folmeris (2010, p. 160) are more specific than Lesh *et al.* on how DBR processes could establish validity. They argue that content or criterion validity is established when there is a recognised need for an intervention and when the design of the intervention is based on scientific knowledge. In addition, the design has to be logical and coherent or consistent to maintain construct validity. The intervention also has to be practical in that it can be realistically used in the settings for which it was designed. Lastly, the intervention needs to be effective and produce the desired outcomes.

Additional resources on how to think of and establish rigor in qualitative work and in naturalistic settings are found in the seminal work of Lincoln and Guba (1981). Accordingly, they argue that in a naturalistic setting credibility, transferability, dependability, and confirmability replace internal validity, external validity, reliability, and objectivity (Lincoln & Guba, 1985, p. 300-301). According to Lincoln and Guba's thinking, validity can be established through prolonged engagement, persistent observation, and triangulation. In their framework, prolonged engagement refers to being in the setting over time to get familiar with the culture of the setting and to gain trust. Persistent observation is helpful in understanding the multiple influences affecting the context, and in developing the discernment to distinguish pervasive and salient features from trivial incidences of influence. In other words, persistent observation provides depth to the study. Triangulation is also well-established in qualitative methodology. It is accepted practice that triangulation can be through sources, methods, investigators, and theories (Patton, 2003). Triangulation by sources has different meanings. In this study it refers to using different sources of the same information, with the intent to establish contextual validation by averting a pattern of distortion. Additional forms of triangulation include triangulation by method (using a mix of qualitative and/or quantitative research methods), and triangulation by investigators where more than one researcher works the field.

It must be remembered that one of the key criticisms against qualitative methods for evaluation is the inherent subjectivity of these techniques. To safeguard against this, Lincoln and Guba (1985, p. 301) suggest the use of the following activities:

- Peer debriefing: an activity which provides an external check on the inquiry process.
- Negative case analysis: an activity which helps to refine the working hypothesis.
- Referential adequacy: a way to check preliminary findings and interpretations against raw data.
- Member checking: directly testing the findings and the interpretations with the human sources from which they have come. Position and use other people throughout the

research process to break through the subjective barrier.

Table 4.16 shows how Lincoln and Guba's recommendations were implemented in this study.

Table 4.16 Techniques to safeguard against researcher subjectivity

Procedures of establishing reliability and validity in the field (Lincoln & Guba, 1985)	**How these principles were implemented in this study**
Prolonged engagement	Worked in the school for two years to get to know the school culture Presented modelling as evidence of my teaching to a panel as part of my Teacher Registration requirement to gain trust
Persistent observation	Taught modelling one term each year to develop data collection instruments as part of my teaching load
Triangulation by source	Used several samples of data sources to construct a psycho-educational profile
Triangulation by method	Combined the DBR with a case study approach to yield a "thick description" of the event
Peer debriefing	Met with a SEN colleague and a mathematics teacher colleague (both senior teachers and team leaders in their departments) as an external check to my teaching and learning initiatives and interpretations
Look for negative evidence	I included the learner who struggled the most with the activities as a case study (Learner C)
Referential adequacy	I collected video and audio material that can be checked against my own findings
Member review	Each week we showed clips from the videotapes to the learners and discussed it with them to get their views and perspectives on what was happening
Multiple perspectives	I work with a range of collaborators who acted as critical friends, cultural advisors, disability advisors, university professors. Also documents such as the EAPs, brain maps, and ALSUP forms represent collaborative processes.

Table 4.16

4.10 ETHICAL CONSIDERATIONS

The learners in this study are vulnerable on many fronts. For example, several of the learners are from a minority group within a given culture, they are in a special education unit, and the research will be conducted by their own teacher, which could impose power relationships.

4.10.1 Special Education Professional Ethical Principles

For the purposes of this research I have chosen to work with the Special Education Professional Ethical Principles promoted by the Council for Exceptional Learners (CEC, 2003). Whereas CEC is an organisation committed to ethical standards and practices, it differs from similar organisations by trying to understand these codes mainly from a special needs perspective. According to the philosophy of CEC (2003, p. ix), special needs educators uphold professional ethical principles when they foster high expectations and growing professionalism, protect the vulnerability of the learners, do no harm to them, and follow national and international protocols. I will discuss each of these traits in more depth below.

4.10.1.1 High expectations and growing professionalism

CEC (2003, p. 1) wants special needs educators to maintain challenging expectations for their learners. This means developing the highest possible learning outcomes. With this in mind, special needs educators are encouraged to promote the inclusion and engagement of learners in their schools through meaningful activities. This research meets the CEC (2003, p. 1) criteria around high expectations and professionalism in so far as the study aims to improve the quality of mathematical learning and teaching for learners in a special education centre. Accordingly, this study is done in conjunction with an internationally recognised university with the intent of generating design principles that will prove beneficial to learners with SEN.

On the other hand, we could compare the ethical considerations of doing the research to the ethical considerations of not doing the research. Without research, the practice of learners with SEN being excluded from mathematical modelling, and thereby from elements of their own curriculum, is more likely to continue. Likewise, by limiting research on modelling we are simultaneously decreasing levels of scientific discourse, professional judgements, insights, and pedagogical skills in this regard. Moreover, collegial collaborations will be cut short, leaving the educator to continue the practice of mathematical modelling in her classroom without scientific scrutiny or input. In the final analysis, not doing the research will most likely impoverish the quality of teaching and the quality of learning, thereby lowering educational outcomes for the learners. The potential benefits of the research to impove teaching and learning are listed in Table 4.17.

Table 4.17 Benefits of the research from an ethical perspective

Benefits to learners	**Benefits to teachers**
Improved learning	Improved teaching
Increased knowledge of mathematics	Growing professional knowledge, skills and judgements
Increased levels of participating in curricular activities	Receiving feedback and evaluations from others
	Understanding more about the specific conditions and resources that are needed to help learners succeed

Table 4.17

4.10.1.2 Protecting the vulnerable

CEC (2003) are concerned with the protection of vulnerable learners. They note that learners with SEN typically need protection in relation to their culture and in relation to their own individual person (CEC, 2003, p. 1).

i) Cultural protection

Both the Feuerstein methodology and the nature of DBR actively promote sensitivity to culture. It differs from traditional research in that it is not a pre-established methodology being applied to a cohort. Instead, DBR is a theory-informed attempt to design *for* a specific cohort in ways that demonstrate respect and consideration for cultural practices. Simply put, DBR is contextualised. The aim is not to impose a method on the learners, but to work with learners' own cultural norms, worldviews, tools, and practices to achieve mathematical outcomes. With this in mind, the learners' dignity, culture, language, and background form an integral part of the design and are supported throughout the process. In addition, two other measures were put in place to ensure cultural protection in this study. As was noted earlier in this chapter, I liaised with a cultural advisor to ensure that my design and my practices were within respected cultural norms. Second, I sought clearance to do the research from *The Central Australian Human Ethics Research* committee. This committee monitors research proposals to ensure that research practices are in line with policies that aim to protect the cultural aspects of minority groups in Australia.

ii) The physical and psychological well-being of the participants

CEC standards remind special needs educators to safeguard learners by not engaging in any practices that could harm learners with SEN.

With respect to physical or psychological harm, the only foreseeable risk to the learners in this study was that of cognitive discomfort should the learner become frustrated with the task. In learning, a specific level of discomfort created by cognitive dissonance is healthy, and even a necessary component of learning (Section 3.4.1). Granted this, the objective of the DBR was to work through cycles of redesigning and evaluating materials to help the learners succeed, thereby minimising unreasonable discomfort through each progressive cycle. Moreover, even in other instructional methods educators can anticipate that at some point in the learning process learners will come across ideas and procedures that cause them confusion and some level of agitation. In addition, there is the risk that the intended design practices can lead to unsatisfactory actual outcomes. For this reason, I tried to create safeguards in the study by using the DBR practices of continual evaluation and reflection, collaboration with others, by a sound consideration of theory, and by deliberately keeping the time period of the implementation phase relatively short.

Additionally, I considered how the use of video could be a source of stress for some learners. In the local context of the school, since learners with SEN typically have significant reading and writing challenges, it has become common practice at the school to take photos of learners' work, and to digitally record verbal interviews with learners' role plays and other learning activities. These materials are typically used as evidence of learning and as alternative forms of assessment. With this in mind, it is school policy for all parents and carers to sign a media release form on enrolment wherein they give permission (or not) for their children to be captured on digital media as a form of displaying their participation in the school. All things considered, the learners who chose to participate were to a large degree familiar with being recorded.

On the other hand, although digital recordings were part of acceptable practice in the context of the local school and therefore available for me to use as a teacher, I could not take advantage of these measures already being in place as a researcher. In contrast to being a teacher, as a researcher I needed to obtain additional permission from the parents and carers and from the learners themselves to use video recordings for research purposes. Additionally, there was an option in the research documents for families or learners who wanted research participation but not media recording. To this end, "camera-free zones" were setup where learners could still be part of their group and participate fully in the mathematical challenges yet fall outside the range of the camera..

It is important to remember that in terms of learners' educational well-being and delivery, DBR does not promise a "quick-fix". Rather, DBR is a stable commitment to a systematic and scientific search for more optimised solutions by collaborating with the learner, family, stakeholders, other professionals, and academics. This research is a way of meeting what the CEC (2003, p. 1) calls the instructional responsibility of special needs educators. According to the CEC it is the responsibility of special needs educators to identify and use instructional methods and curricula that are appropriate and effective in meeting the individual needs of the learners. Not only are special educators to identify these methods and resources, they are also to participate in the selection and use of the instructional methods and resources to increase the effectiveness of their practice. Moreover, they need to create safe and effective learning environments, which contribute to fulfilment of needs, stimulation of learning, and self-concept.

Part of showing instructional responsibility in the context of the research is meeting the ethical obligation that all learners will have access to the same activities and to the same quality and quantity of educational input as the participants. The research did not take the place of or usurp education in the classroom. Lessons continued as per the day's timetable. The only difference between the participants and the non-participants was that the participants' contributions were analysed after hours for publishing purposes.

Furthermore, learners were invited to participate in the study through the cultural advisor who acted as an intermediary. Care was taken not to pressure or disadvantage in any way the learners who did not want to participate in the study. Likewise, learners had the option of participating in the research without being recorded. Additionally, the learners who participated also had the opportunity to withdraw should they wish to do so, without it affecting their education in any way. To this end, the cultural advisor met with the learners, as a group, and one-to-one, without me present, before and during the research.

Lastly, all workers (researcher and cultural advisor) who had contact with the learners during the research project had an Ochre card. An Ochre card shows that the individual has been cleared by the police as having no previous criminal offences that could potentially impact on the safety of learners.

4.10.1.3 Follow national and international protocols

Three applications have been made to ensure that I practiced within national and international professional standards. Applications were made to the *Human Research Ethics Committee* of the University of Stellenbosch for review from the South African side (see Addendum A); to the *Department of Education in the Northern Territory's* (see Addendum B) research committee for approval from the Australian side; and to *The Central Australian Human Ethics Research* group (see Addendum C) to ensure that the ethical practices are in line with policies that protect the cultural aspects of a minority group. All three groups granted permission for the study to continue.

4.10.1.4 Working closely with other professionals and with families

As was noted previously, several professionals other than the researcher-teacher participated in the research, for example, the cultural advisor, the reviewers of the ethical committees, the supervisors at the university, and colleagues who became "critical friends". Their roles were noted earlier in this chapter.

On the whole, family members and carers were not directly involved in the research. Contact was made with families to request consent. Input from the families into the study was also obtained through secondary resources such as EAP meetings, notes in the school files, and so on.

With respect to informed consent, the researcher approached family members, explained the research to them, answered any questions they may have had, and requested their written permission to invite their learner to be part of the research project. Only learners whose parents/carers gave permission were invited by the cultural intermediary to participate in the research. The families whose learners were involved in the research will be informed of the results of the research at the end of the project either in writing or in person.

4.10.1.5 Teacher as researcher

There are certain roles I can fulfil as a teacher without needing additional consent. For example, as a teacher, I can trial new teaching methods in my class; expect learners to participate in class and use my teaching role to secure their participation; adopt an expert view and advise parents and learners in certain matters; access school records freely; make reasonable requests to the support staff in my class and expect them to follow through on these. As a researcher, however, I had to obtain written permission from several stakeholders (principal, ethical committees, parents and carers, the learners themselves using an intermediary, and the LSA in my class) with regard to these practices.

4.10.1.6 Protecting the identities of the learners

Prior to the study, the following parameters were set out to protect the identity of the learners with SEN:

- The school's name will not be mentioned in the research. No addresses will be used.
- The town's name will not be mentioned in the research.
- The names of the learners will be replaced with pseudonyms.
- No images of the learners' faces will be published.
- The study will discuss general traits of the learners (such as cognitive functions) and not personalised, unique individual traits that make them vulnerable to identification.
- The only persons who will see the video material are the researcher and the learners themselves. The researcher will transcribe it using alternative non-identifiable identities for collaborative reflection and publishing purposes.

4.10.1.7 Protecting the data

During the research, the digital data were stored on USB sticks. Hard copies of data, including samples of learners' work and the USB sticks, were stored in a locked filing system in the special needs office in the school building, which could only be accessed by authorised staff.

Now that the study has been completed, the data will be kept for five years, should there be any need for a second look at the data at a later stage. A copy of the data will be locked in a safe in my home. Only the supervisors and the principal will have access once they have submitted a written request. Data from the study will be presented in the form of a doctoral thesis.

4.11 CONCLUSION

This chapter is about design and data associated with the design. For this reason, I provide a summary of the chapter in Table 4.18 to show the link between the different research tasks in this study and their relation to the use of data in this study.

Table 4.18 Data matrix

TASK	RESEARCH QUESTION	RATIONALE	DATA REQUIRED	SOURCE OF DATA
A		Define the critical characteristics of learning environments for learners with SEN	Research, evaluation and theoretical papers on suitable pedagogical practices for learners with disabilities Include SEN, inclusive and general practices	Research journals, conference papers, and books
B		Define the critical characteristics of modelling as an instructional task	Mathematics education method	Research journals, conference papers, and books International workshops Consult with practitioners and experts
C		Establish learners' psycho-educational profiles that focus on specific strengths and weaknesses	Developmental history of the learners showing learning challenges Previous support structures implemented at school Get to know the learners and how they learn in a classroom situation Get those collaborating in the design to get to know the learners' behaviour in a classroom	Documents in school files EAP meetings which include parents/caregivers Normal classes - I am the cohort's teacher Co-teaching the class with a colleague, who is a critical friend/advisor

D	Primary research question: How can the theory of mathematical modelling be used with special needs learners to improve their understanding of location?	Instructional design	**Broad principles:** Knowledge of accepted instructional principles for learners with SEN. Knowledge of modelling. **Localised principles:** Knowledge of the specific strengths and vulnerabilities of the learners Knowledge of the school (curriculum, resources, access to ICT, classroom management)	International workshop - Feuerstein - DBR Teacher-as-researcher
E		Pre-Evaluation: Screening, Co-Teaching (Tryout of approach, not activities), Practitioner Consultation, Consultation with Cultural Advisor, Expert Review	How suitable is the design for learners with SEN? What are the main strengths and shortcomings of the tasks and data collection techniques and instruments in relation to the learners' needs?	Interviews by appointment
F	Secondary research question: How do the learners' characteristics taken from their psycho-educational profiles affect their modelling?	How does the individual presentation of their disability affect their engagement and learning during modelling tasks? How can they be supported?	Observations, voice and video recordings of learners doing modelling tasks Samples of learners' work	Normal mathematics classes at school

F	Secondary research question: How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?	How do Feuerstein's cognitive mechanisms present and affect their model-building efforts and their learning?	Observations, voice and video recordings of learners doing modelling tasks Samples of learners' work	Normal mathematics classes at school
F	Secondary research question: What evidence of learning can be found in the analysis of learners' reasoning and representations over time?	What evidence is there that the learners are learning? To what extent are they reaching academic goals?	Observations, voice and video recordings of learners using the programme Samples of learners' work	Normal mathematics classes at school
G	Secondary research question: How does the learners' learning correspond with the proposed learning trajectory? To what extent does modelling benefit and/or impede the mathematical learning of learners with SEN in respect to location?	Overall reflection and drawing out design principles	Observations, voice and video recordings of learners using the programme Samples of learners' work Focus group interviews with the learners	Normal mathematics classes at school Pastoral care lessons at school

H	Secondary research question: How viable is modelling as an instructional approach in a SEN classroom based on an **analysis of learning characteristics, processes, and representations in mathematical modelling of middle school learners with special needs?**	Publication	A systematic design and defence of the study that moves it beyond "class project" into academic literature	Completed thesis

Table 4.18

CHAPTER 5
PROCESSING AND INTERPRETING DATA

5.1 INTRODUCTION

This chapter is divided into three separate sections. Section A documents the design and implementation of three mathematical modelling challenges called the *Easter Egg Hunt Challenge,* the *Defuse the Bomb Challenge* and the *Fly the Helicopter Challenge.* These challenges were implemented daily into my own SEN classroom at a middle school in the Northern Territory of Australia as part of the learners' daily mathematics programme and extended over four weeks. I treated each challenge as a separate cycle of intervention, and described its planning, its implementation, its evaluation, and its subsequent revision. To clarify, the implementation phase is described in terms of Sekerák's (2010) delineation of the modelling phases of learners, which are problem identification, model building, and verification. The evaluation part had three separate processes attached to it — a process of self-reflection, a process of collaborations with co-practitioners, and a learner focus-group session with the learners to hear their reflections and opinions of the modelling challenge. The focus of the evaluation was reflecting on how to adjust the approach instead of the refinement of the actual learning tasks, with the latter being more typical practice in DBR.

In Section B, I examine the learners' learning from my perspective as a teacher-researcher. To this end, I used three individual case studies to provide detailed descriptions of the characteristics, processes, and representations of these learners in relation to modelling. These case studies varied in terms of the learners' aetiologies, their attainment levels in mathematics, and their involvement in the modelling tasks. I analysed three of the secondary research questions that applied directly to the learners after each case study.

Section C discusses the rest of the research questions in relation to data from the research.

5.2. FRAMEWORK AND METHOD OF ANALYSIS

5.2.1 Analysing the data

In analysing the data, I followed standard coding processes, for example, those outlined by Saldaña (2013), Matthew, Miles and Huberman (1994) and Baptiste (2001) in Table 5.1 below. I used an inductive data analyses approach, looking for themes related to my research questions and coded accordingly.

Table 5.1 The process of coding the data

<table>
<tr><th></th><th>Saldaña (2013, p. 2-13) Steps</th><th>Matthew, Miles and Huberman (1994) Stages</th><th>Baptiste (2001) Pragmatical Approach</th><th>Software</th></tr>
<tr><td>Transcribing</td><td colspan="3">Data from interviews, field notes, video clips, audio recordings, files, learner focus group interviews, conversations with collaborators</td><td>MS Word</td></tr>
<tr><td>Coding</td><td>Summarises, distils, condenses data, does not always reduce data (p. 2)</td><td rowspan="2">Data Reduction</td><td rowspan="2">Defining the analysis</td><td rowspan="4">HyperRESEARCH</td></tr>
<tr><td>Subcoding</td><td>Cycles of coding and subcoding</td></tr>
<tr><td>Categories, Labels</td><td>Create a system of classification Explicit</td><td rowspan="2">Data Ordering and Display</td><td rowspan="2">Classifying data</td></tr>
<tr><td>Themes and Patterns</td><td>Outcome of analytical reflection on categories Subtle or implicit</td></tr>
<tr><td>Examination of themes</td><td>Asking questions about the themes e.g. "Why are they there?"</td><td rowspan="2">Drawing and Verifying conclusions</td><td>Making connections</td><td>MS Word</td></tr>
<tr><td>Reconnecting with research questions</td><td>Theorising</td><td>Conveying the message</td><td>MS Word and MS Excel</td></tr>
</table>

Table 5.1

Figure 5. 1Processes of how the intervention was implemented, evaluated and refined

5.2.2 Units of analysis

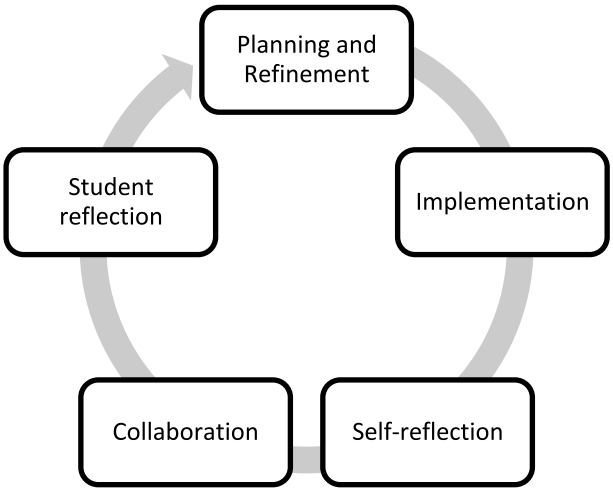


Figure 5.1

In the first section, which covers the design, its implementation, and its subsequent refinement, the unit of analysis is the design itself. I describe how it was implemented, note common themes on learners' responses to the intervention, followed by an evaluation of the intervention (first on my own and then with others) to prepare for subsequent refinements. The planning and adjustment phases overlap in my discussion, as the adjustments became part of the planning phase of the next cycle. The phases of the process are depicted in Figure 5.1.

In the second section, the unit of analysis is the individual learners. Three cases are considered. These three have been selected from the sample, based on their attendance and to exemplify learners with different types of diagnoses, and, therefore, with different emphases on the support mechanisms that they may need.

5.2.3 Assessments

5.2.3.1 Matrix for evaluating modelling behaviour

The matrix for evaluating modelling behaviour in Table 5.2 was taken from the work of Galbraith and Clatworthy (1990, p. 140). The grid contains assessment criteria and standards and was established to construct a profile of a learner's performance across a sequence of modelling tasks. I use this grid to evaluate learners' modelling capacity as it would be seen from a mainstream perspective.

Table 5.2 A mainstream example of how to assess modelling in a classroom

Criteria	**Standard 1**	**Standard 2**	**Standard 3**
Ability to specify problem clearly	Is able to proceed only when clues are given	Can extract clues from information and translate them into a clear expression of the problem to be solved	Is able to perform as for S2 and in addition can clarify a problem when information is open ended, insufficient, and redundant
Ability to formulate an appropriate model: choose variables and find relationships	Is able to proceed only when clues are provided	Is able to determine important factors and develop relationships with a minimum of assistance	Is able to determine important factors and develop relationships independently where no clues exist
Ability to solve the mathematical problem, including the mathematical solution, interpretation, validation, evaluation/refinement	Is able to solve the mathematical problem given substantial assistance through clues and hints	Is able to solve the basic problem with little or no assistance Generally unable to refine the model	Is able to solve the basic problem independently Is able to evaluate and refine the model
Ability to communicate results in a written and oral form	Is able to communicate reasonably in regard to layout (including use of visuals), presentation, conciseness, and orally, with some prompting	Is able to communicate clearly with good use of aids and without prompting	Is able to communicate clearly with outstanding presentation including innovative creative features

Table 5.2

5.2.3.2 Matrix for evaluating depth of knowledge

Webb's (1997) Depth of Knowledge (DOK) matrix was developed for teachers to help to evaluate the degree to which their task designs are promoting cognitive depth in learning. To this end, the matrix is designed to evaluate the depth of cognitive processes that an instructional task design requires from learners, and not the difficulty of the task itself. In this study, I use the matrix from the perspective of the learners, by looking at the depth of knowledge the learners are applying when they construct their models. The matrix for the study based on Webb's (1997) work is found in Table 5.3. Essentially the matrix evaluates the connectedness of ideas that learners' use in their models.

Table 5.3 Webb (1997) Depth of Knowledge Matrix

Level 1	**Level 2**	**Level 3**	**Level 4**
Recall a mathematical fact, term, principle or concept Perform a routine procedure or basic computation Locate details	Use mathematical information Have conceptual knowledge Select appropriate procedures Perform two or more steps with decision points along the way Solve routine problems Organise and display	Develop a plan or sequence of steps Make decisions Justify decisions Solve problems that are abstract, complex, and non-routine More than one possible solution Support solutions and judgements with evidence	An investigation or application to the real world Non-routine problems Solve over extended time Requires multiple sources of information

Table 5.3

5.3 A SUMMARY OF THE LEARNERS' PROFILES

An important step in the design process was to find out more about the background of the learners and their individual strengths and vulnerabilities, so that the instructional tasks could be personalised by matching them to learners' developmental levels, strengths, and vulnerabilities.

The next part of the study relates to Task F of the research, where Task F is as follows:

Task F: The implementation of three modelling tasks in a SEN classroom.

In the first section of Task F, I provide a rich description of the implementation from my perspective as a teacher. As was noted in the previous chapter, a rich description is important to establish transfer to extended situations by other practitioners. Moreover, Patton (2003) states that the researcher needs to keep the descriptive side and the data analysis side separate for readers to have the opportunity to draw their own conclusions from the data. In the second section, I analyse three case studies with regard to the research questions related to Task F, namely:

- What is the relation (if any) between the learning behaviours during mathematical modelling and the pscyho-educational profiles? What strengths and assets emerge from the learners during the activities? What barriers emerge?
- Which of the primary cognitive functions as identified by Feuerstein emerge and which remain absent? How can more vulnerable cognitive functions be strengthened in the context of modelling?
- What evidence of learning can be found in the analysis of learners' reasoning and representations over time?

SECTION A: A DESCRIPTION OF THE DESIGN PHASES

5.4. CHALLENGE 1: EASTER EGG HUNT

5.4.1 Planning the approach

Support was planned with technology, social processes, and cognitive processes in mind.

I did not want learners to get caught up in the novelty of technology at the expense of their learning. The Easter Egg Hunt had the option of doing a virtual Easter Egg Hunt using *Google Earth.* I knew that the learners were familiar with *Google Earth* as we used it on several occasions in general lessons for research the term before. For example, in English lessons, learners gave short presentations on their country (birth place and family area) and used *Google Earth* to this end. Likewise, during Social Science learners visited various countries by "flying over" them with *Google Earth* during history and geography lessons.

In terms of social processes, the learners' psycho-educational profiles showed that they struggled with social issues and for this reason it was anticipated that group work would present certain challenges. Additionally, from being with the learners the term before I knew that they were comfortable sharing the same physical space, but tended to work parallel within that space. To support them in their collaborative learning, I decided to join their groups as a group member. Becoming a member of the group would allow me to demonstrate group practices and, in doing so, support vicarious learning. Furthermore, the group structure itself would be informed by the learners' choice of a virtual or an actual location. To explain, those who chose a virtual location would form one group and those who chose the school would form another. Since the LSA took extended leave, there was no additional staffing support. I explained to the learners the "need for secrecy" that is, taking measures to prevent the other group from overhearing the location of the treasure. To this end, I suggested that we do our planning in the side room off the classroom, in separate groups, one group at a time. This enabled me to work with each group on its own first, without having the other group in the same space.

In terms of supporting the learners' cognitive processes, being part of their group allowed me to mediate in a very direct way between the learner and the material. I intended to mediate mostly through types of Socratic questioning. The first mathematics challenge was differentiated down to a Year 1 level, to make room for all the other adjustments the learners had to make in terms of using a new method to mathematics learning. Although I did modelling tasks with my other SEN classes, I had not taught this class of learners modelling previously, thereby anticipating that modelling would most likely be a new experience for them.

Error-checking or validation by others was built into design in a natural way, in that learners had to follow directions to a treasure marker. If the directions were wrong, the groups would not reach the treasure. Again, from the previous term's experience, I realised that the learners typically struggled with error-checking their own work. With this in mind, the setup was that each group provide the others with a second wave of error checking. To explain, the first wave of error-checking would be internal with members checking their directions amongst themselves in their respective groups. The second wave of error-checking would happen when the groups had to follow one another's directions to the treasure. Should the group searching for the treasure not understand the directions, or should the directions prove incorrect, they needed to ask the group that developed the set of direction for clarification. I anticipated that once the group looking for the treasure began to question the group that gave directions to them, that the latter would be able to recognise and correct some of the errors they may have made. It is important to realise that in this challenge the mathematical model that learners had to construct was the set of directions. Consequently, by correcting their directions, learners were verifying and refining their models at the same time.

In terms of aspects around autonomy, choice-making, and self-determination, I used the idea of co-agency by giving the learners the following options to:

- invite other classes to participate in the hunt or to limit the hunt to class members only
- choose an actual or a virtual location (both familiar to all the learners)
- decide where to hide the treasure
- decide what the treasure would be (given an AU$10 budget)

On the day of the actual treasure hunt, we informed staff that the learners would be running around the school premises looking for treasure as part of their learning activity for the day.

5.4.2 Implementing the approach through the modelling cycles of learners

5.4.2.1 Presentation of the problem

i) Session 1

The class discussed the *Easter Egg Hunt Challenge*, gathering as a whole group around a table in the classroom. I explained that our class would have an Easter egg hunt as part of the school's Easter celebrations. Accordingly, the challenge was to think of a good spot to hide a treasure, and then plan a set of directions to it. They could either plan an actual treasure hunt that would take place on the school grounds, or a virtual one that would take place in town but on *Google Earth.* Since all the learners have either grown up in town or have lived there for a reasonably long time, for example, since they were 7 years old, they were very familiar with the layout of the town and knew their way around. Care was taken to make sure that they understood the problem and to answer their questions. At first, the learners were confused about the idea of a virtual Easter egg hunt, thinking that I wanted them to go into the actual town. I took some time explaining the idea to them, helping them understand what was meant by a virtual treasure spot. Once they understood the concept, learners wanted to know where the actual treasure would be, considering that the destination was virtual. We agreed that the treasure would be kept in class, and that we would create treasure markers. If the groups found the virtual treasure spot, they would receive a treasure marker, which would allow them to choose a treasure from the treasure pile in the class. Likewise, the school group would place a treasure marker somewhere on the school property, and when found, learners could come back to class to select their treasure. After I clarified these details, the class voted on whether they wanted to invite other classes to participate or not, and on whether it should be a virtual or actual experience. The majority of the class chose to limit the activity to class members only. In this study, Group 1 in the *Easter Egg Hunt Challenge* refers to the group who chose to hide the treasure marker on the actual school grounds, and Group 2 refers to learners who chose the virtual route. At this point, the treasure is snacks that we will share together as a group.

5.4.2.2 Modelling Phase 1: Problem Identification

ii) Session 2

In the context of this challenge, the starting point for the learners was to decide where they wanted to hide the treasure. Deciding where to place the treasure validates which locational information to input into their model and which to omit. Group 1 consisted of two learners, a boy and a girl, and Group 2 of four learners, two boys and two girls. As explained earlier, I worked with Group 1 in a side room to my classroom, while Group 2 had time on their iPads in the main classroom area. During their group session, learners from Group 1 worked parallel to one another, in individual books, mostly making very little eye contact, and occasionally looking at what the other had written down. Consequently, in an attempt to help them connect, I suggested that we first brainstorm possible locations, compile a written list with our options, select a location from the list, explain which location we would prefer, then draw a map to it and decide on the treasure. Both learners participated in these processes, mostly directing their questions and comments to me as a teacher. During this session, they spoke once to each other, which was when I left the room to fetch some tissues. Much time was taken up by the learners requesting the correct spellings of various words. At the point where they needed to choose a location from the list they compiled, one member suggested that they decide on separate locations and work independently and the other agreed. I went along with their arrangements on the decision that some children may need to work parallel first before allowing others to cross over into a more interpersonal space. My strategy was to support them towards positive interdependence by taking the step of "checking in" with one another, for example, by saying to one another, "This is what I think...What do you think about it?"

The members of Group 2 also went into parallel mode, yet two of the members kept up a conversation throughout the process. Their conversation started off with bantering, singing, joking, and giggling and then took the form of a running record of "show and tell." To illustrate, the conversation was in the manner of "This is where I am on *Google Earth*" (Peer 1) and a response, "This is where I am now" (Peer 2). For the most part, the conversation was not interactive in a task-orientation or problem-solving way. A common theme, with the exception of one learner, was to first and foremost find their homes on *Google Earth*, and then move on from there. Since there was already a conversation running, I played a more suppressed group facilitator role than with Group 1, occasionally reminding the learners that they needed to find a location in town. For the most part, although the learners were sitting around a table in a group structure, each one seemed absorbed in their own location-finding on *Google Earth*. Towards the end of the lesson, I tried to get the learners to express their ideas, put them on the table so to speak, discuss them and then vote on one. As with the other group, I was trying to get them to brainstorm options together. When asked what they had decided, the learners would tell me their locations but would not share with the group, On the whole, I was not successful in getting the group to discuss options together. Eventually, the bell rang for assembly and I suggested that we take the first option that was given to me by a learner, namely, to hide it in a particular shop in a local shopping centre.

5.4.2.3 Modelling Phase 2: Construction of the model

Session 3:

In light of the absence of the normal LSA, a substitute relief worker came to the class that day during the mathematics lesson. She made treasure markers with the one group, where the treasure markers were a variety of 3D shapes made out of match sticks and jelly tubes, while I worked with the other group on the Easter Egg Hunt in the side room to the classroom. We agreed to swop groups after 25 minutes, which was halfway through the lesson. A learner from Group 2 was unsettled by the appearance of the new relief worker and spontaneously came and joined Group 1 in the side room, which meant that Group 1 now had three learners (two boys and a girl). The new grouping caused some friction and name-calling at first, which led me to remind the learners of our school values with relation to respecting others. Learners mostly worked independently on their directions towards the treasure markers. The new member to the group was talkative, bouncing his ideas off me, again in a kind of parallel talk. The others listened and occasionally contributed by laughing at, or objecting to, some of his ideas from the side. The girl in the group made a slightly more interactive attempt at conversation when she tried to answer his question on the name of the room. I continued the same strategy as the day before, which was letting them work independently on their maps and directions (models), and, once they had developed these, to share them with the other group members and to receive feedback from them. The individual members shared their directions while the others listened, but nobody gave any form of feedback.

Group 2 now had three learners. In contrast to the day before, two learners were bouncing ideas off one another, agreeing and disagreeing on directions around town, while a third stood by and followed their discussion. Although this was significant in terms of collaborative thinking, another member was being completely disregarded. This member was particularly shy and sensitive, and was being left on the outskirts of the group. Making an effort to include her, I interrupted the group and explained to them that typically in a group, different group members assume different roles. To this end, I suggested that they continue their discussion, but that one group member control the computer, while at the same time another write down the directions and so on. Furthermore, it was put to the group that we should involve a particular member as the scribe of the group, which they agreed to. After that, I intervened frequently to remind the group to work closely with the scribe to get their ideas written down, and not to steamroll ahead with the discussion. I also showed the scribe what it meant to be a scribe. For this reason, instead of a flowing conversation, it became a case of "Wait, we have to write that down." At one point during the discussion the learners realised that one of them was talking about a walking route and another was talking about a car route. Learners corrected one another and self-corrected with relation to the image on *Google Earth*. Moreover, learners did not know how to give directions in regards to a roundabout. At the end of the session, I asked Group 2 to recheck what was written by the scribe by following the scribe's directions and making changes that were necessary as they went along. I read out the scribe's work as she was reluctant to speak long sentences in public settings, and requested that the other group members follow the directions on the screen to see if they were correct. They pointed out some changes, which were recorded.

5.4.2.4 Modelling Phase 3: Verification of the model

Session 4

As per Sekerák's (2010) delineation, the final phase in the model is testing the model against reality, that is, to look for a close match between the mathematical model and its expression of reality and the reality itself — reality in this case being the following of the directions to the treasure. If the directions were adequate, and if they were followed correctly, learners should find the treasure marker. On the day of the hunt, we extended the mathematics lesson over two sessions. In the first session, learners were asked to set up their clues, so that the Easter Egg Hunt Challenge could start. The setup phase introduced several different behaviours. Some learners were absent due to family camping arrangements. One learner worked quietly in a focused way at his desk, while another ran around the room, giggling and playing with the furniture and equipment. Still another learner wrote the team's directions on the board, while somebody helped by holding the book for her, yet the two of them did not speak to each other while doing so. Moreover, whereas some learners were very comfortable with setting up clues around the school, others did not want to leave the classroom.

Once it was all set up, Group 2 presented their directions first. As was noted before, two members of Group 2 had written the directions on the board for Group 1 to follow. They did not include any of the amendments made the previous day, but paid no attention to the edits and simply wrote the first version of the scribe's work, even though the edits were all on the same page and right next to the original version. The learner who wrote on the board was very reluctant to speak in class, and the one holding the book could not read, which may partly explain why they did not pick up the errors they were making. A timekeeper was appointed and each learner from Group 1 was given three minutes to try and get to the treasure by following the directions on the board. Since Group 2 did not incorporate the corrections into their version of directions, the members from Group 1 soon became lost. At this point, it was challenging to help the class see that it was not the member from Group 1 moving through *Google Earth* that was at fault, but that it was the directions given to the member that were faulty. One member from Group 2 blamed the person sitting at the computer and wanted him to move away so that he could "show him" where to go. Yet, none of the learners made any attempt to guide the person by fixing the directions. At that point, I interceded, trying to help them understand that we needed to correct the directions and not blame the person following the directions, nor give them an easy route to the treasure by showing where to go, thereby giving away the treasure spot. Moreover, as the timekeeper could not keep time, it led to some Group members objecting that it was unfair they had only a short time on the computer, whereas others had a longer time. Once Group 2's treasure was located, we moved onto Group 1's set of directions.

Group 1 left their clues on A4 plastic sheets around the school. Each clue had directions to the following clue. It was not possible to film this session, as learners were running in all directions following the clues to find the treasure marker. At one point, learners were so excited to get to the next clue that they left the clue with the directions to the next clue behind, just running blindly. They soon realised that they did not know where to go and had to run back to get the "map", thereafter remembering to take the clues with them to help them keep track of the directions.

At the end of the lesson, learners who found the treasure markers could choose a prize out of a lucky dip and then share it with the class by way of an indoor "class picnic" to celebrate Easter. Whereas some learners were happy to share the prize, others hid theirs in their bags and refused to share with the group.

5.4.3 Reflective Evaluation

5.4.3.1 From a teaching perspective:

- There was a strong pull in some groups towards working in parallel on individual tasks, which undermined the notions of positive interdependence and genuine collaboration.
- For the most part, learners were happy to listen to one another and to engage in show and tell scripts, but fell short of drawing the other person into their thinking with the objective of joint decision-making.
- I identified that I overcompensated in my role of researcher in trying to get the learners to collaborate to the point of "squashing" some of their ideas.
- My transcript revealed that I used language that was not conducive to quality mediation.
- The activities were set in a personal space, namely their own school and town, yet within the space the learners drew on personalised knowledge as the source for their solutions (where to locate the treasure), in particular knowledge that was frequent and had happy memories.
- Spelling impeded the flow of ideas. On the positive side, it facilitated literacy.
- Learners who could not follow the directions were blamed for being "wrong", whereas the reality was that some directions were missing information. The learners did not take into account that their directions were faulty and that the group following their directions were actually doing the right thing according to the directions.
- It was difficult to balance the knowledge component with the social component, for example, by trying to get Group 2 to involve the shy member and draw her into the group as scribe. As a result, I kept interrupting their reasoning processes.

5.4.3.2 From a learning perspective:

i) Gains in learning:

- The learners met the given learning and success criteria, which were to give and follow directions, using directional terms such as forward, backwards, turn left, turn right.
- The learners could apply these concepts to familiar locations, in this case their school and their town.
- New connections were formed in terms of angles and degrees, for example that "turn left" could be expressed as "turn 90 degrees left". Consequently, the task helped some learners develop the meaning of the concept by having to apply it.
- The learners confronted the use of mathematical terms in the real world, for example, by working out what it meant to turn 90° [ninety degrees] left and how to give directions when there is a roundabout in the road.
- It promoted active involvement, in that, aside from the morning setup sections, the learners were all involved in the tasks.
- Four of the learners asked if "we could do it again soon", whereas a fifth learner assumed we would, by saying "When we do this again?" I interpreted these comments from the learners as showing their enjoyment of the activity.
- The task was conducive to language development. It developed grammar, spelling, and idioms.
- It was a practical life skill, allowing functional life skills to blend with the general curriculum. For example, some learners realised that a person walking and another driving a car would need different directions, and that it was best to take the clues or maps with you when you are travelling to a destination instead of leaving them behind.
- Learners were able to transfer these concepts to another lesson. During the English session, they were tracing the story of *Planes*, a

movie where a crop sprayer races across the world visiting several countries. Some learners had difficulty finding countries such as Nepal on the globe, and I asked them to direct each other there by using directional words. They could say for instance "Move left, go up, a bit more right" and so on.

ii) Gaps in learning:

- The learners were reluctant to combine directions with distance.
- Some learners could not do very basic computations (addition and subtraction up to ten) mentally.
- Learners were unfamiliar with more advanced concepts associated with turns (relationships with angles and notations of degrees).
- Some learners could not tell the time.

5.4.4 Collaborative Evaluation

I met with a SEN practitioner over that weekend to reflect on the week. Since we had co-taught the previous semester, she was familiar with my teaching style and with the classroom dynamics. In fact, she taught many of the learners during their primary school years. This practitioner is also the team leader of the SEN unit, meaning that she is up to date with all the EAP processes and views of others involved in the learners' lives, such as the parents, the therapists, and so on.

We discussed the following three challenges:

- Instructional task matching: There are huge gaps in the learners' understanding of mathematics, in so far as content that would be too easy for one learner is too difficult for another. Whereas one learner was working with Year 8 concepts, another was working at Year 1 level.
- It was apparent that certain learners were working in parallel, show and tell mode of activity. We debated the pros and cons of leaving them in that mode or of trying to

move them on from there.

- Considering that I was hosting the first focus group interview with the learners the upcoming week, we debated how valid as evidence of learning the perceptions of their own learning could be.

5.4.5 Learners' reflection

For the most part, learners were very positive about the activity. Common themes were that they learnt how to give directions and how to work with angles. Only one learner felt that he did not learn from the experience. Learners' suggestions on how to improve the activities so that they could learn more from them ranged from more in depth teaching on angles to buying more chocolates.

5.5 CHALLENGE 2: DEFUSE THE BOMB

5.5.1 Adapting the approach

The following changes were implemented after the reflection and evaluation period of the first cycle. In an attempt to move the learners from parallel work towards collaborative learning, the task was set up with the intent to develop positive interdependence. To explain, learners worked with a partner, that is, two learners per device. Ideally, one learner would turn the dial (watching from the front), with the other reporting when the rotors lined up (watching from the back). To facilitate communication, I continued instructing the learners to make their ideas known to each other by telling their partners what they were doing. For example, the person turning the dial had to tell the partner where he/she stopped, "I stopped at number 3", and how he/she got there on the dial, "three and a half turns clockwise", which the partner then had to record. In this way, the activity followed on from the previous challenge in this regard as well, that is, by emphasising the group skill of one person being the scribe.

Whereas in the first challenge I supported the learners' development of collaborative learning by separating each group into a different location and by joining the group as a group member, in this challenge I moved closer to the ideal of modelling by having groups in the same room, with me as the teacher playing a facilitator role rather than being a group member.

5.5.2 Implementing the approach through the modelling cycles of learners

5.5.2.1 Presentation of the problem

It was necessary for the learners to focus on mathematical outcomes and not to be caught up in trying to figure out the internal mechanisms of the combination lock. Therefore, I took time to explain the workings of the combination lock to the learners, in particular how the front knobs turned the rotors at the back and that for the bomb to be defused, the mouths of the rotors at the back all had to line up (See Figure 5.2). This time I allocated partners, telling the learners who would work together and deliberately used a different combination to the one that emerged from the previous mathematics challenge. This was done for the sake of seeing how different group combinations affect the modelling processes of the learners. We put a timer on the board, showing a countdown from 20 minutes to create a sense of make-believe and fun. I accidently forgot to inform the learners that the rotors had to line up from the back to the front, meaning that the back one had to line up first, then the middle one, and lastly the front one. It meant that the problem could still be solved, but with a lot more turns involved. The LSA picked up on this after one learner became anxious about not "getting it" quite soon after the learners started working with the device, and I thereafter informed the learners accordingly, that is, to line the rotors up from the back.

Figure 5.2

A photo of the "bomb" showing its rotors lining up at the back.

Figure 5.2

5.5.2.2 Modelling Phase 1: Problem Identification

The model building started by gathering information through the senses, turning the knob, and seeing its effect. In other words, the relationship between turning the dial and aligning the rotors at the back into a specific position had to be established through observation. Learners could see when they were successful, as the wire of the defuse knob would slip into the groove that occurs when the rotors are lined up in the right position. It became apparent that learners wanted time alone with the device to figure it out. To this end, they pulled the devices away from their partners, without taking their partners into account. In other words, when learners chose to hold and explore the devices, they typically held them in a way which blocked the partner's view of the device and from what they were doing.

5.5.2.3 Modelling Phase 2: Construction of the model

Session 1 and 2

The learners had to construct a model of the code that would defuse the bomb. Each bomb had a unique code, which prevented the learners from bypassing working out their own solutions by copying off one another. In order to provide the details required, learners had to pay attention to the accuracy of their data collection in that they had to match the numbers on the dial to the alignment of the rotors. They also had to combine multiple sources of information, including the numbers on the dial, the number of turns to reach the number on the dial, and the directions of the turns (clockwise or anticlockwise).

The following behaviours were observed at the beginning: Two learners started by verbally expressing some numbers (that is, guessing "5, 9, 6, 4") then turning the dial to these numbers and seeing if the rotors lined up. After this, they no longer verbalised the numbers but only concentrated on the movement of the dial and the alignment of the rotors. Shortly thereafter, they announced that they had defused the bomb, yet when asked for the combination, they went silent. In their focus on the relation between the dial and the rotor alignment, they neglected to pay attention to the numbers themselves, and to the overall process of recording the numbers.
One learner guessed a number, turned the dial, guessed a number, turned the dial, and occasionally glanced at the back and looked at the rotors, but largely persisted in this way until I asked the team to swop partners, as a way of giving everyone a chance to work with the dials. Learners worked in pairs on the activity for three days. Due to name calling and some learners not wanting to sit in close proximity with other learners, I decided to rearrange the partners on the second day, for the sake of having more positive partnerships.

5.5.2.4 Modelling Phase 3: Verification of the model

Session 3

On this day, one group was ready to have their directions verified, while the other group was still developing their solution. As with the Easter Egg Hunt, I decided to use the second group to verify the results of the first group, in conjunction with the first group. The idea was that members from the second group had to defuse the first group's bomb (and vice versa) by using the combination code compiled by the first group. An additional component to error-checking was to give the learners opportunities of "giving" and "following" directions as per the mathematics descriptions in ACARA. The first group had to sit in on the process and monitor two conditions. Was the second group following their directions? Were the directions that they gave to the second group accurate? Accordingly, in the event of the second group not being able to defuse the bomb, that is align the rotors in the right position by following the directions of the first group, it could mean that the first group did not follow the directions correctly and/or that the directions themselves were not correct. The first group had to decide which of these options it was, and adapt accordingly. Several challenges were experienced and addressed, mostly by the members themselves. For the most part, learners found working with fractions challenging, with the exception of one learner who had a good grasp of fractions. To explain, they were uncertain of the symbols for fractions — both in how to write fractions down and how to read fractions out if they were written down. It was resolved by the learner who was familiar with fraction symbolisation filling in for those who did not know. Moreover, learners struggled applying the meaning of fractions. Whereas they understood ½ turn and ¼ turn when in a standardised format (for example, the move from 0 to 3 on the dial), they could not conserve it from an oblique angle (for example, the move from 5 to 8 on the dial). Additionally, they had difficulty with the meaning of mixed fractions, for example, what it meant to turn the dial 1 ¼ turns. Again, the one learner who knew fractions tried to explain to the others what he meant through words and hand signals, in effect showing them how to turn. When the bomb could not be defused on the first attempt, the group who had developed the directions argued that the fault was with the members of the group who were following the directions, and not with their directions per se. Markedly, none of the learners (the group members giving directions and the group members following directions) noticed the errors in the information. The errors that were made by the first group were related to fractions, saying ½ turn when it was actually ¾ turn from one number on the dial to the other, and this was not being picked up.

5.5.3 Reflective Evaluation

5.5.3.1 From a teaching perspective:

- Interestingly enough, three of the learners used their non-teaching time (e.g. being at school early before the bell or finishing their work before the others) to play with the device, sitting on a chair trying to" figure it out".
- It seemed that I needed to give the learners' time to work on the problem on their own before expecting them to work together.
- At the onset of this challenge, learners were not passing the device to their partners, but keeping it to themselves. While keeping it to themselves they shut off their partners and made no spontaneous attempt over time to invite their partner in. To counteract this, I intervened by asking them to swop over and give the device to their partners. In this regard, the knowledge-social dilemma emerged again. To explain, by telling learners to hand the device over to their partners so that everyone could have a turn, I interrupted their reasoning processes and was dismissive of the modelling principle that group members should really negotiate the terms on their own. Yet, my intent was for the learners to become aware of social norms

and how their actions were affecting others.

- Moreover there was tension between Learner B and her partner during Day 1. It was difficult to find the right group match with certain learners. In this instance, when the learner-partner became aware that his partner was less knowledgeable than him, he subsequently engaged in name-calling and belittling.
- I wondered if the challenge was too hard for them, but during the learner interviews, they expressed optimism and excitement and enthusiastically informed me that they had learnt from the activity.

5.5.3.2 From a learning perspective

i) Gains in learning

- Some learners had direct practice with mathematical concepts like symbols and recording.
- Learners were engaged in thinking outside of the typical mathematics lesson.
- The task facilitated repetition without tediousness.
- Learners seemed to enjoy the challenge, even using time to work on the problem before school and during school when they had a break from other class activities.

ii) Gaps in learning

- Most of the learners knew the meaning and terms clockwise and anticlockwise. Only one learner was unsure.
- Aside from one learner, the rest struggled with fractions:
  - A learner confused half a turn with 6 on the dial. She seemed to be relating her work back to time on a clock face, which was a topic we covered the previous term. In other words, regardless of where the turn started, if it ended at 6 on the dial, she would say that that was half a turn.

- Most of the learners did not conserve the idea of fractions. As was explained earlier, they recognised fractions on the dial that corresponded to standardised depictions such as are typical in drawings in a textbook or on a worksheet as well as certain numbers on the dial (1/4 is 0 to 3 on the dial, and ½ is 0 to 6), but they did not recognise oblique versions (1/4 is also 5 to 8 on the dial).
- Four learners did not know how to use symbols for quarter and half. They were unsure of how to spell a quarter in English, and they did not know how to write it as a mathematics symbol.

5.5.4 Collaborative Evaluation

During that weekend I met with the schools' team leader on mathematics. We mostly discussed three issues:

- What counts as evidence of learning?
  How do we know that learners are learning mathematics? He argued that from his perspective, engagement was key to learning. Tasks had to be designed to draw learners in and to get them engaged. He explained that he uses three ways to engage typically disengaged learners, namely, attention-grabbing props, games, and interesting apps.

- Why do learners find it so hard to error-check? Kahneman's (2011) work, for example, argues that error-checking seems to be a separate system of cognition, which he refers to as System 2 (Section 3.3.9). Is this system underdeveloped in learners with SEN? Would they consequently benefit from more explicit training in this regard, and if so, what would this kind of training look like in classroom practice? Or, is error-checking more knowledge related? That is, we cannot fix what we do not know. We also spoke about error-checking from a cultural perspective. Perhaps learners were reluctant to error-check as it was against their cultural norms to draw attention to themselves or others in this manner? For example, would error-checking be seen as a "shame job" from a cultural angle?

- How should educators evaluate non-routine, unfamiliar problem-solving to produce evidence of learning? It is current practice in the local school to provide a pre-test on a topic, then teach the topic for a set period, and thereafter give learners the same test as a post-test. The difference in learners' results between the pre- and post-test is taken as evidence of learning. Given that, how would this work in problem-solving, seeing that by presenting exactly the same problem or even a similar one on the post-test, the criteria of problems being "unfamiliar" and "novel" to the learner are consequently nullified. In other words, solving the same problem twice nullifies the novelty element of the challenge by making the unfamiliar familiar.

As was noted earlier, another event happened later that week, which influenced my design and made me change course thereafter. Our school arranged for a professional development session with a professor in mathematics from an Australian university. Interestingly enough, his professional development session was on how to teach problem-solving mathematics to learners. None of the SEN teachers were invited to attend his session, yet he agreed to an appointment with me outside of his training schedule.

We discussed three issues:

- The first related to the difficulty around the social dynamics of group work, and whether group work led to knowledge gains or to knowledge losses with respect to the individual's learning. He argued that his own view was to allow time for the learners to think about the problem on their own first and then to collaborate.

- The second was a continuation of my discussion with the mathematics collaborator with respect to matching evidence of learning to problem-solving. Put differently, how would we know if a learner is learning mathematics? What does learning look like in problem-solving? It is easy to be drawn into a kind of mathematical circular reasoning by arguing that since the learners solved the problem, they are learning, and since learners learnt they are solving the problem. Yet, it is a theoretical possibility to solve a problem successfully and not learn anything by it. All things considered, how does a teacher explicitly defend that a learner has learnt something or has not learnt anything by solving that particular problem? As a teacher, there is some kind of intuitive knowledge that a certain learner understood, whereas another did not grasp the concept. In light of the introduction of evidence-based practices in our school, how should we make this tacit knowledge of a teacher measurable?

- The third was related to the role of manipulatives or concrete material in problem-solving with learners with SEN. Should educators encourage it, or should we fade it out? His position was that concrete materials are typically used with mathematical reasoning at a basic level, but that it could also have unintended consequences for developing more advanced reasoning, that is, in situations where the reasoning relies on patterns not found in concrete materials.

Furthermore, arrangements were made for the cultural advisor to visit the class that week. She observed a lesson and thereafter spent time alone with each learner to monitor the effect of the research on their wellbeing, and to follow up with the learners in terms of them continuing with the research or withdrawing from it at that point.

5.5.5 Learners' reflection

The learners' response to the activity was very positive and enthusiastic. For example, during the focus group session, when asked if they felt that they learnt from the activity, the "shy scribe" surprised us all by loudly responding "Yes! Yes! Yes! Yes!" Remarks from the learners included that they enjoyed figuring out the combination, that the task got them working, and that they liked the element of challenge in the activity.

5.6 CHALLENGE 3: FLY THE HELICOPTER

There were three objectives to the task, namely, to create a top view diagram of the school, to overlay it with a self-designed grid map, and to give the directions to specific destinations around the school using the grid map and coordinates from it as a reference system. The other team then had to follow the directions and the grid reference system by flying a remote-controlled toy helicopter to the areas of the school demarcated by the coordinates.

5.6.1 Adapting the approach

After my consultation with the visiting mathematics professor, I decided to adapt my approach by allowing more time for the learners to work on their own before collaborating. For example, I decided that all learners would draw a top-view model of the school to give them time with the problem on their own, and thereafter get together and debate which drawing to select for the grid reference system for the purpose of collaborating.

I also decided to allow the groups to negotiate more of the problem-solving and social processes on their own. At the same time, I wanted to explore peer tutoring dynamics. Consequently, my LSA and I agreed to approach this challenge in the following way: In terms of the modelling task, we would explicitly remind learners of the task and its criteria. Likewise, in terms of their social processes, we would remind learners of the expectation that they work together as a team by assuming different roles if necessary, by making sure that they are sharing their ideas with each other, and by working towards joint decisions. Furthermore, we agreed that when learners asked for help, we would refer them back to their team and would only intervene in the groups if really necessary. This arrangement meant that I did not assume the role of mediating any cognitive functions in a direct or deliberate manner. Instead, I stepped back to see the extent to which group members would take on this role towards one another.

5.6.2 Implementing the approach through the modelling cycles of learners

5.6.2.1 Presentation of the problem

I was unsure of the learners' familiarity with the concept of a top view. Comments from reports, follow-ups with previous teachers, and the collaborative planning documents from the previous year indicated that the learners knew the names and properties of 2D and 3D shapes. I was not able to verify whether they were previously taught to draw 3D shapes or how to derive top, front, or side views from given 3D shapes. For this reason, I presented the overall problem to the learners, but explained that we first needed to learn more about 3D shapes — how to build them from nets, how to draw them on dot paper, and how to derive a top view from a drawing or shape. For the duration of this challenge, groups were assigned based on the social characteristics of the learners, meaning those who could sit in a group and be civil to one another as opposed to combinations that resulted in name-calling and teasing. A related issue was that two new learners enrolled in the unit that day. The new learners teamed up and started a faction with some of the learners from the class during recess.

5.6.2.2 Modelling Phase 1: Problem Identification

For learners to identify the problem in the challenge, they needed to know what a top view was. To this end, they constructed a top view of the school with foam blocks, and watched a tutorial on how to draw 3D shapes and how to derive a top view from a given shape.

i) Session 1: Building a model of the school from top view

The learners started playing with the blocks, while I set up the *Google Earth* image. There was a lot of imagination in their chatter as they built their own structures. I reminded them of the learning outcomes of the activity — that they had to build a model of the school as seen from top view, and that they had to work as a team in accomplishing this. A laptop with a top view of the school was placed next to them on the table. I noticed they had relatively few blocks and that in their play they were taking blocks from one another. For this reason, I went to the store room to fetch more blocks. During this time, one of the newcomers came into room, and one of the group members sitting at the table (the one that was previously in the faction) picked some blocks off the table and threw them at the newcomer, while swearing at her. In response, the newcomer picked the blocks off the floor, threw them back at the group and ran out the door. Thereafter, another group member grabbed more of the blocks off the table and started throwing them at the others, starting a game. One learner jumped up to come and call me, while the others continued with their game. On my return, I reprimanded them and asked them to pick up the blocks. For a while thereafter everyone pulled back and became quiet. One learner started drawing on the table and then played with his iPad, another just toyed with the blocks without looking up, while two sat quietly. A minute or two later, the learners resumed building structures, both working parallel, while a third learner passed the blocks to his peer who was building, while the other learner played with the blocks in his hands, watching the others. They were in strong parallel mode, which made me ask them if they thought that they were working as a team. Every learner in the group said, "Yes, *I am* building this…", "Yes, *I am* building this…", without realising the paradox in it. There were two instances of genuine problem-solving that happened during this activity, meaning that they moved from parallel into collaborative interactions. The one related to the learner who was watching, who suggested a solution to the design of the learner who was building; the other learner weighed up the suggestion and then produced a third alternative, which incorporated aspects from both learners' ideas. The other problem-solving action happened when a part of the school was not visible and learners had to adjust the computer screen. The learners spontaneously moved into one another's space, clustered around the screen, made suggestions, tried them out, and made counter suggestions.

Towards the end of the activity, a particular group member was very resistant to feedback on her work from others in her group. The group wanted her to scale her building down to match the proportions of the other learner's structure. However, when she did not want to comply with their request, her peer leaned over and took half her foam blocks away as a way of reducing her building's size. Following this incident, she was tearful and upset.

Considering that the group had four members, it was apparent that one learner was building a top view of the school, while the second was building another top view of the school next to him and out of proportion to his. A third member was passing the blocks, and the fourth one mostly watched. On balance, aside from the suggestion mentioned earlier, the building expressed one person's thinking and not that of the others. After the group work sessions, I asked the learners to build individual models. One of these individual models was more accurate than the "combined model". When I asked that learner why he had not contributed his ideas during the group session, he said that he "didn't want to cause trouble".

ii) Session 2: Developing an understanding of top view

The following day, the class watched a short video tutorial on how to draw 3D shapes. One learner came back from recess, seemingly angry and upset, and left the class, informing us that he was going home. The rest stayed and started watching the tutorial. A few minutes later the learner who had left came back, sat down on a bean bag and got caught up in the video. After a recap of the tutorial I ask them to attempt the task demonstrated in the video on their iPads, using the 3D drawing app. (The drawing corresponded to some of the 3D foam blocks they had used the previous day.) This was an individual task. Learners were not asked to work in a group, but they were encouraged to seek help from a peer if they needed it. In other words, the idea was to get those who grasped the concept to "teach" it to those who were struggling, thereby encouraging peer tutoring. To this end, one learner showed the LSA how to use the programme. Learners were again telling others what they were doing, in a parallel mode with a common theme of "Look at my one". One learner could not get her iPad to work, so she spent the lesson painstakingly designing her own dot paper on the computer.

5.6.2.3 Modelling Phase 3: Construction of the model

i) Session 3

The next day, the class continued watching the educational video, seeing how to derive front, top, and side views of the shape in general, but with more attention given to constructing a top view than to the others. The instructional goal of the activity was to create an awareness of the concept and meaning of "top view", rather than achieving mastery in deriving accurate top-view representations from 3D objects.

Thereafter, learners were shown the school from *Google Earth.* They could spontaneously identify this as a top-view rendering, which they then had to draw. Learners did not have to draw on their iPads, but they chose to do because it "was funner".

ii) Session 4: Minecraft (Filler activity):

During this session, the LSA and I were setting up the group activity where learners had to choose a drawing to be used in the grid reference design. To this end, we were checking the learners' work, making sure that everybody's drawings were printed and ready, that they had no names on them, and that they had a photocopy of the school on each table. While getting ready for the activity, I left a box of Minecraft (a video game) templates on the table. These templates were 3D nets, with a Minecraft theme overlayed. To explain, learners were constructing a cube from a net, but the cube would resemble a Minecraft chest or cauldron when finished. Likewise, instead of constructing a rectangular prism, they were constructing a zombie from Minecraft.

No groups were assigned. The box was left on the table and the learners could engage with the activity as they wanted to in terms of who to work with or not, and which Minecraft characters or objects they wanted to construct. The objects and characters had different levels of complexity to them. Whereas certain characters and objects had single nets that seemed simple and straightforward, others like the spider or the zombie became more complex and required several nets to be combined to produce the design. For the most part, the learners sat around the table, except for one who sat away from the group on the swing but then joined the group after a while. For the most part, learners worked parallel and used a type of "show and tell" interaction. The activity generated a significant amount of talk, during which learners kept up a verbal running record of what they were doing, while checking in on the others. Several very imaginative scenarios emerged in their conversations as they constructed the props. In the end, learners became so caught up in the activity that I decided to postpone the group activity and let them continue with the nets for that session.

iii) Session 5

In this session, learners worked in groups to choose the drawing they thought was the best representation of the school from amongst all the drawings produced the day before. The names of learners were removed from these drawings to help learners focus on the features of the drawing without getting caught up in personalities. Moreover, they were given an A3 coloured photocopy of the school image on which the drawing was based as a model for comparison. They had to justify their decision by working out three reasons for their choice. Once they shared their ideas with the class, the class voted on one drawing that we could use for the grid reference.

iv) Session 6: Measuring

Now that the learners had a top-view drawing, they had to decide on a scale and measure out a scaled map of the drawing. The top-view drawings were on graph paper. The intended instructional task was to scale by equating each block on the graph paper to a measurement. To this end, their scaling methods could be informal, with one block equating to one step, for example, or formal, with one block representing one meter, depending on their understanding of measurement. Learners disregarded the scaling instruction and spontaneously started to measure the lines of the school, each one working on their own page, measuring all the lines on that page. I tried to shift the learners' attention back from a measuring task to a scaling task by reminding them of the need to deduce a scale from the individual blocks. Yet, the class continued measuring each line of the drawing. I decided to let them be and use this as an opportunity for assessing their current understanding of measuring, since this was a learning topic scheduled for the following term. Learners who could not measure with a ruler wanted me to help them. I diverted them back to the group, asking the ones who could measure to teach those who could not. In trying to help one another, learners' efforts took the form of a show and tell scenario, "like this... see".

Since the learners all measured their own copies of the drawing, I wanted them to transfer their results onto one drawing. In other words, take the information from the three drawings measured by three different learners and transfer/combine the information into one drawing that could be used by the group to scale the oval. It must be remembered that all three drawings were exactly the same as they were copies of the drawing chosen by the class the day before. The task had two objectives. First, it would serve as a form of error-checking. For example, if all had the same measurements for a building, they could just transfer it to the clean drawing. Yet, if different group members had different measurements, they could re-measure that section. After the instruction, some learners started remeasuring their work again, which made me interrupt the class to explain what I meant by transferring the information.

There was a noticeable difference between the two groups. Group A worked hard and seemed focused, whereas Group B played a series of games, ranging from hangman to pretending to be space men to having a sword fight with the rulers. I asked them to get on with the task at hand, but they had real difficulty in settling at this point. I deliberately did not intervene further as I wanted to see if they could settle themselves down as a group. One member from Group B tried to unsettle Group A by going to their table and name-calling. After a while, the LSA went to sit at their table, reminding them of the need to complete their task. At that point, two of the members settled while the third one ran out of the room. The two members left at the table began working together, taking turns to measure and to write down the measurements. The third member came back into class, but still couldn't settle. He tried to re-engage with his group by joking with them and then by banging loudly on furniture, but the group members paid no attention to him and continued with their work. Eventually, after being reprimanded for banging on the furniture, he settled next to the fish tank and constructed a fishing line from the rulers. Thereafter, he spent the rest of the lesson trying to catch the fish, modifying his fishing rod as he went along. The two groups were engaged in the work until Group 1 announced that they had finished the task. At that point, one of the members in Group 2 went over, had a look at Group 1's work, and thereafter stopped working with his team member.

v) Scaling on the oval

Learners continued in their groups from the previous day. A learner from another class walked in with a balloon and caused some distraction by starting a "hit-the-balloon" game until his LSA came to take him back to his class. Some learners engaged in the balloon game, others took no notice of it.

Measuring wheels were available for learners to measure out their scales. I demonstrated to the learners how the measuring wheel worked, that is, one full turn counts for 1 metre. At this point, a learner jumped up, took the wheel and measured the width of the room, saying that it was 4 metres. We discussed the idea of a scale. Learners knew that it was linked to "measurements" and making versions that are "bigger and smaller". Thereafter, they had to create a scale for their project by deciding how many of the blocks would equate to 1 metre on their drawing. I thought that since the learners spontaneously demonstrated to me that they understood the measuring wheel I could bypass informal measurements and go straight into meters. The group that was so focused the previous day was unfocused and two learners withdrew, one going to the rocking chair and the other to the couch, which left the remaining partner without any members to talk to.

On the other hand, the group that was so unsettled the previous day was very settled and involved in a discussion on whether 1 metre or ½ metre would be more suitable. Their discussion was along the lines of one learner saying to his peer, *"I say 1 metre"*, and his peer responding, *"I say* ½ metre", with the first learner responding, "*Well, I say 1metre"*. At this point in their conversation I interrupted them by asking them to think about "*What is good about 1 metre and what is bad about 1 metre?*", and to do the same for ½ metre. Thereafter, they concluded that using 1 metre would be "easier". The groups had to decide whether they wanted to do the whole school as a group, or whether different groups should do different sections of the school, combining their buildings to form a whole school. They opted for the latter and we discussed which group should do which sections. At this point I handed out a ream of security tape to each learner. I decided on security tape to create the lines of the scaled map as it was bright and visible. The learners immediately started playing with it by touching it and wearing it like a bangle. Thereafter the class left for the oval.

Learners had to measure out the scale with their measuring wheels, lay the security tape down on the field, and hold it down by placing rocks on the tape. Some learners played with the wheels, pushing them along the oval. One learner threw his drawing away. Two members asked "What must we do now?" I explained to the group how to look at the blocks on the drawing and then measure out the length with the measuring wheel. The group whose member had thrown the paper away realised that they needed the paper, and started looking for it. The groups typically had one person walking with the wheel, counting out loudly, and a partner walking next to the wheel. One group had two members with a wheel each. Instead of working on different sections, they all measured the same line next to one another. All the groups managed to measure out the first line of their drawing, and checked in with me to tell me that they had done so, shouting "Miss, we've done it" or "42 metres, Miss!". Thereafter they had to put down the tape to mark the line. In spite of rather large rocks that were placed on the tape, the wind blew the tape away. It was a particular windy day. At this stage, a learner started wrapping another learner up in security tape. Learners abandoned the mathematics project and started chasing one another around the oval, wrapping one another up in security tape. One particular learner had so much fun playing the game that she afterwards requested that we do the activity again on her birthday. Only one learner did not join in the game, but stood beside me on the field. I let them play for the rest of the lesson as I could not see a way forward with the tape in the strong wind. I also doubted that the tiny toy helicopter would be able to manage those kinds of conditions.

vi) Scaling in a classroom

Due to the wind, we had to move the project inside. We used the room adjacent to our classroom, moving the furniture to the side. It was quite a large room, twice the size of our typical classrooms.

During this session, Group 1 worked together well. One member took the lead and adjusted their scale to 1 block representing a ¼ metre, instead of 1 metre as per the oval. Group 1 took turns and measured out the buildings. They ran out of space towards the end, when there was no additional room left for the rest of their scaled drawing. On the other hand, Group 2 had more significant challenges. There were three members in this group. The first member was very keen to learn and made a real effort drawing pictures to work out the scale, measuring with the wheel, and recording his data. The other member sat back and watched the activity, without giving much input. The third member of Group B stayed in the classroom, occasionally coming in to see what we were doing and to play with the measuring wheel and other objects in the room. When reprimanded by the LSA for being rude to her, he went back to the classroom.

i) Making a grid reference system

Four of the learners could make a grid reference system independently and fairly quickly. Two other learners were unsure, and resorted to copying from the others in their group. Most learners used letters of the alphabet on the one side, and numbers on the other, whereas one learner used letters of the alphabet on both sides. They could work out the coordinates and then set out to fly the helicopter. When flying the helicopter to given coordinates, learners moved out of parallel mode into one another's space, collaborating, picking the helicopter up when it crashed and giving it back to the flyer, encouraging one another, and explaining to one another how to use the device.

5.6.2.4 Modelling Phase 3: Verification of the model

Unlike the other activities, which had a clear progression through the modelling cycle of problem identification, model construction, and model verification, this challenge proved more ambiguous in this regard. This was in part due to the adaptations that were added to the original HLT as the activity progressed. Three levels of verification emerged at different stages during the challenge. The first process of verification was in choosing a top view drawing, the second in scaling the classroom, and the third in flying to coordinates on the grid reference.

- The drawings of the learners were presented to the class — all names were removed and learners were asked to maintain the anonymity by not pointing out their own drawings. Learners were assigned to groups. Both groups had three members. Each group had to select one drawing that they considered to be the best representation of the school and to justify their decision to the class. A large A3 colour photocopy of the school from *Google Earth* was placed on each desk. Learners made their individual choices, "I like that one", without consulting with their partners and without looking at photocopied image of the school from *Google Earth.* These decisions were made very quickly, within seconds of looking at the drawings and no reasons were given at the time. I asked them to check in with their partners, to choose one as a group, and then to explain to the other group why they thought that drawing was the best. The only guideline I gave the groups was that they had to choose a drawing that "best matched the school, and provide three reasons". I did not specify any further criteria. Two learners used criteria that they related back to the structure of the school by comparing the presence of buildings, the shape of the buildings, and so on, between the image and the drawings. Others evaluated it on a subjective level, for example, "That one is horrible. That one is good", and still others used superficial criteria such as "That one has black edges (from the printer). It looks burnt". One group was offended when another group challenged them on their criteria.

- Scaling in the classroom provided a natural type of verification. Their scaled drawings either fitted in or they didn't.

- Most learners seemed confident in making the grids and reading off the coordinates, and then got caught up in learning how to fly the helicopter.

5.6.2.5 From a teaching perspective

- I was surprised at the learners' interest in the Minecraft activity. It generated a noticeable level of imagination and engagement. Correspondingly, learners requested that I purchase some of the other Minecraft templates for the class.

- I found it difficult to fit the subtasks of the challenge into the modelling framework. This was largely because there were so many "other concepts" that they needed to learn to do the task. To this end, I wondered if some of these other concepts in the form of subtasks should be taught directly to save time or be made into individual modelling tasks of their own. Put differently, should sub-tasks be divided into mini-cycles of their own with problem-identification, task implementation, and evaluation phase?
- Learners ignored the instructions and went back to what they knew rather than evaluating the learning objectives. For example, they worked on perimeter, not on scale. Perhaps the idea of scale was not known to them, and therefore they interpreted the question in light of what they did know, and what they thought was expected of them.
- I wondered what my pedagogical response should be to the play behaviours that emerged during the activities. In other words, there were several incidences in this cycle where the knowledge-social dilemma emerged. Needless to say, from a knowledge perspective, playing games when you should be doing mathematics is not a good thing. However, when considering these learners' backgrounds, for example, histories of trauma and conditions such as autism, and that they are frequently victimised at school, play could be interpreted as a very positive development.
- I was surprised at the learners' challenges with transferring information across to a construct on a "combined data" drawing. From my own perspective, I considered it an easy task that would only take a few minutes, but they took a long time to complete it.

5.6.2.6 From a learning perspectives

i) Gains in learning:

- Learners worked with top view across several different modes.
- There was an opportunity to practice measurement.
- Learners gained familiarity with an important mathematical tool — the grid

reference system.

- Four situations emerged where the learners spontaneously moved out of parallel mode into real problem-solving mode: Adjusting the screen so that all of the school was visible on *Google Earth*, deciding on creating a Minecraft city, and flying the helicopter. Whereas these three were non-academic related, the fourth was academic related, and concerned the issue of adjusting the structure of the foam blocks to accommodate an alternative solution.

ii) Gaps in learning:

- The learners who could not measure with a ruler all ran into the same obstacle. They were uncertain where to start. They wanted to measure from the bottom of the ruler, rather than from the zero. Once it was pointed out that the zero was the starting place, they adapted to using a ruler quite quickly.
- Learners did not understand decimals, as it is used on the ruler to move between cm and mm.
- One learner confused squares and rectangles during the block building task.
- Some learners did not use units, others used the wrong unit of measurement (e.g. m instead of cm or mm)
- In the room, when the furniture got in the way of the measuring, some learners would measure around the furniture, instead of predicting that they had to mentally go "through the furniture" and out the other end in a straight line.
- Some also did not seem to make the connection that if their drawings were running into furniture, their scale was too big and had to be adapted.
- Their work showed a misunderstanding of proportion.
- For the most part, learners did not label their work.
- Learners needed some more work on mathematics language, especially around measurement, for example, using terms such as length and width.

5.6.3 Learners' reflections

The discussion in the final focus group session became a discussion of the learners' experiences of mathematics at school. The question leading up to the diversion was "What we as educators could do to help them learn mathematics?" This question was asked after several learners expressed concern over the disruptive behaviour of the one peer during the challenge. With this in mind, they stated that "it doesn't work if some people aren't involved". This then led into the question of how we as a class could make learning together work for one another, and what we need to change to include this particular peer into the activities. At that point, learners spoke about how they hated mathematics, found it boring, wished it was more fun, didn't understand why they had to spend so much time working out sums if they could just use the calculator, and how they thought they were not going to use school mathematics in their future lives as adults. Only one learner indicated that he liked mathematics and that he could see its relevance for his future. Two learners discussed how hard mathematics was for them. In short, they wanted mathematics to be "fun" before they felt that they would benefit from it.

5.7 SUMMARY OF THE ACTUAL LEARNING TRAJECTORY

Table 5.4 provides a summary of how the HLT was implemented and realised in the classroom, and how it evolved in terms of key aspects related to the design.

Table 5.4 A summary of how the HLT developed in practice

	Challenge 1	**Challenge 2**	**Challenge 3**
Group work	Groups changed after the visiting relief worker Mixed, boys and girls Choice of task created a natural group	Worked as partners (two per "bomb") Partners were assigned by teacher Tried to put different partners to previous activity Partners were re-assigned after conflict between partners Partners were mixed, boys with girls	Kept learners together who did not victimise one another Mixed, boys and girls

	Challenge 1	**Challenge 2**	**Challenge 3**
Principles from Design	Choice: (Co-Agency, learners chose medium Appropriate use of Technology: (*Google Earth*) Bridge to real life: (giving and following directions). Change in rhythm: change in roles (hide the treasure and find the treasure) Change in environment (looking for the treasure in different places, not just sitting in one spot in the classroom)	Somatosensory (something the learners could touch and look at) Challenging (a non-routine, unfamiliar problem) Inbuilt differentiation (all learners could enter the task by turning the knobs, but their levels of data collection were different)	Multimodal. Learners presented top view in many different ways (foam blocks, drawings, chalk on the cardboard, overlaid by a grid reference)
Support for social processes	Became group member, at times became the dominant group member to facilitate progress	Became a group facilitator	Became a group observer (with occasional input)
Support for cognitive processes provided	Mediation	Mediation	No mediation
Feuerstein Focus	Elaboration (processing)	Input (data collection)	Output (data output)
Feuerstein's correspondence with modelling phases.	Refinement and expansion of idea	Problem identification and data collection for model	Model verification, including communication, assessing validity, and feedback
HLT	Followed HLT Only changed the time of mathematics (did it over two sessions in the morning), instead of one lesson after recess as per normal routine. Needed time to setup. Learners went to other classes after mathematics (could not extend that time slot)	Followed HLT	Did not follow HLT Additional activities: Minecraft Measurement Scaling

	Challenge 1	**Challenge 2**	**Challenge 3**
Influence from collaborators	Task design and ideas for developing positive interdependence	Engagement is important to learning	Give learners time on own
Role of LSA	Away on extended leave	Explained the bomb mechanism to learners who came to class late after the long weekend on the second day of the activity	Sat with a group when they had difficulty settling Did not get involved in the task at that time

Table 5.4

CHAPTER 6
AN ANALYSIS OF THE CASE STUDIES AND AN EVALUATION OF THE DESIGN

6.1 AN OVERVIEW OF THE CASE STUDIES

In this chapter, I analyse three case studies in relation to the research **questions** attached to Task F of the study. Table 6.1 provides a comparative overview of each of the cases. As indicated previously, these cases were selected for their variance in that they present different conditions, different genders, different levels of mathematical attainment, and that they faced different types of barriers during the modelling tasks.

Table 6.1 A comparative overview of the three cases

Area	**Learner A**	**Learner B**	**Learner C**
Age	13	13	12
Gender	Male	Female	Male
Diagnosis	Autism Spectrum Disorder	Global Development Delay	Foetal Alcohol Spectrum Disorder
Ongoing challenges	Poor social skills Victimisation by peers (safety concerns)	Visual processing difficulties Concentration Language development Victimisation by peers (safety concerns)	Behaviour challenges Concentration challenges
Support at school (Past)	Placed in special needs school at preschool Transferred to mainstream Had special needs educator support in mainstream classroom	Placed in Early Childhood Development class Full time LSA	Withdrawal to SEN class for weekly sessions One-on-one LSA support
Support at school (Present)	Place in SEN unit	Place in SEN unit	Place in SEN unit

Area	Learner A	Learner B	Learner C
Level of mathematics (Tested in March 2014)	Year 3 - Year 4 (3.3 OnDemand Testing)	Year 0 - Year 1 (0.5 OnDemand)	Year 1 (PATMaths. Year 1)
Level of individual programme in mathematics	Year 8	Year 2	Year 1 - 2
Medication	Nil	Medication for epilepsy	Medication for attention-deficit disorder
EAP goals	To choose appropriate sensory items to hold to compensate for inappropriate body behaviours To listen respectfully to others and respond appropriately in the classroom and in the playground	To stay on task for 5 minutes To differentiate between safe and unsafe environments To make safe choices	To increase on-task engagement to allow successful completion of negotiated learning activities/tasks To increase his positive social interactions with his peers

Table 6.1

6.2 CASE STUDY: LEARNER A

6.2.1 Psycho-educational profile of Learner A

6.2.1.1 Data from school files (chronologically)

Learner A is a 13 year old male who has an ongoing history of concerns regarding his adaptive behaviours, social interactions, and behaviours in class. He was diagnosed with autism spectrum disorder when he was 5 years old by a paediatrician. The support and intervention he has received up to this point in his schooling is documented in Table 6.2

Table 6.2 Support and intervention history of Learner A

Learner A	**Event**	**Assessment**	**Results of assessment**	**Support**
Age 4	Started speaking for the first time			
Age 5		Paediatrician	Autism	Started school in special needs unit
		Speech and Language Assessment	Moderate to severe delay in language	Speech and language therapy
Age 6	Transferred to mainstream school. Repeated Year 1			Support from special needs educator
Age 7	Concerns from school in regards to emotional state, behavioural, relationships, and task completion			
Age 8		Speech therapy review	Mild to moderate language delays (improved). Moderate delays with problem solving skills. Severe difficulties in making inferences and determining causes. Atypical social communication skills.	Continue to receive special needs educational support in a mainstream setting

Learner A	**Event**	**Assessment**	**Results of assessment**	**Support**
		Occupational Therapy assessment	Visual motor and visual perceptual skills in the average range. Fine motor coordination skills were in the below average range. Poor trunk stability/low tone.	
		School psychological assessment	Overall adaptive functioning: Extremely low range	Social skills training at school
Age 9	Transferred to a new school Difficulties in adjusting	Wechsler Intelligence Scale for Children: Fourth Edition (WISC-IV), Australian Standardised Edition	Within the borderline range of intellectual functioning (3rd percentile).	
		Childhood Autism Rating Scale (CARS)	Moderately Greatest difficulty with relating to people, anxiety, and body use.	
Age 11	Continued to have difficulties at school with peers. Frequent target of teasing. Oral language shows a marked improvement, but still having difficulty with written work and reading	*National Assessment Program – Literacy and Numeracy (*NAPLAN)	Scored marginally below the national average in reading and numeracy. Scored in 1/3 percentile in all other subject areas	

Learner A	Event	Assessment	Results of assessment	Support
Age 12	Transferring from primary school to middle school	The Vineland Adaptive Behaviour Scales: Second Edition (Vineland-II)	Adaptive behaviour – moderately low. Moderately low in communication, daily living skills, and socialisation.	Transferred to SEN unit
Age 13		Hearing test	Normal	

Table 6.2

To summarise, Learner A was placed into a SEN unit at Middle School rather than in a mainstream setting, based on the scores from his standardised tests and after consultation with his father. These scores indicated that he had a low level of intellectual disabilities (3rd percentile) and adaptive behaviours (3rd percentile) and that he needed support for his impaired social functioning, language disorder, poor communication, unusual body language, inappropriate behaviours, and anxiety.

6.2.1.2 Data from brain map (function and structure of brain)

His lower scores in the brain stem were related to his body movements, constantly having to keep something in his mouth, for example. The lower scores in the cerebellum areas were in respect of his poor sense of coordination, bumping into objects, challenges with handwriting, the way he walks, unusual gait. The lower limbic areas relate to his history of ongoing social difficulties, especially in relation to his peers. And his cognitive scores relate to current academic performance at school not being on par with his peers, his testing on language, mathematics, and so on.

Figure 6. 1 Functional brain map: Learner A

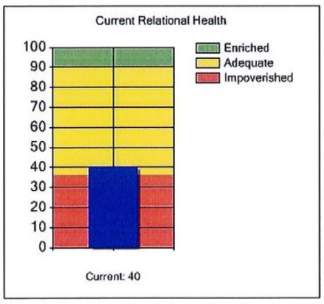
NMI
childtrauma.org

The ChildTrauma Academy
www.ChildTrauma.org

Current CNS Functionality

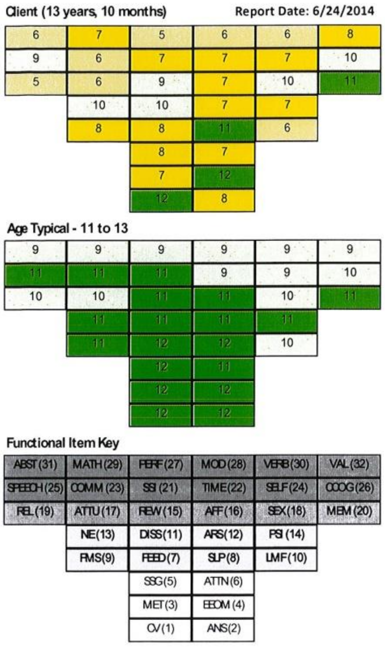
	Brainstem	Client	Typical
1	Cardiovascular/ANS	12	12
2	Autonomic Regulation	8	12
3	Temperature regulation/Metabolism	7	12
4	Extraocular Eye Movements	12	12
5	Suck/Swallow/Gag	8	12
6	Attention/Tracking	7	11
	DE/Cerebellum		
7	Feeding/Appetite	8	12
8	Sleep	11	12
9	Fine Motor Skills	8	11
10	Coordination/Large Motor Functioning	6	10
11	Dissociative Continuum	10	11
12	Arousal Continuum	7	11
13	Neuroendocrine/Hypothalamic	10	11
14	Primary Sensory Integration	7	11
	Limbic		
15	Reward	9	11
16	Affect Regulation/Mood	7	11
17	Attunement/Empathy	6	10
18	Psychosexual	10	10
19	Relational/Attachment	5	10
20	Short-term memory/Learning	11	11
	Cortex		
21	Somato/Motorsensory Integration	7	11
22	Sense Time/Delay Gratification	7	9
23	Communication Expressive/Receptive	6	11
24	Self Awareness/Self Image	7	9
25	Speech/Articulation	9	11
26	Concrete Cognition	10	10
	Frontal Cortex		
27	Non-verbal Cognition	5	9
28	Modulate Reactivity/Impulsivity	6	9
29	Math/Symbolic Cognition	7	9
30	Reading/Verbal	6	9
31	Abstract/Reflective Cognition	6	9
32	Values/Beliefs/Morality	8	9
	Total	**253**	**338**

Current CNS Confidence Level: Moderate



Current Relational Health Confidence Level: Low

Functional Brain Map(s) and Key



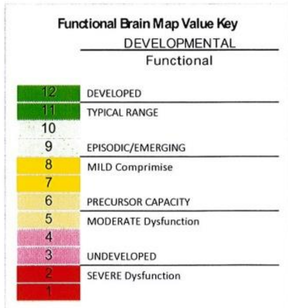
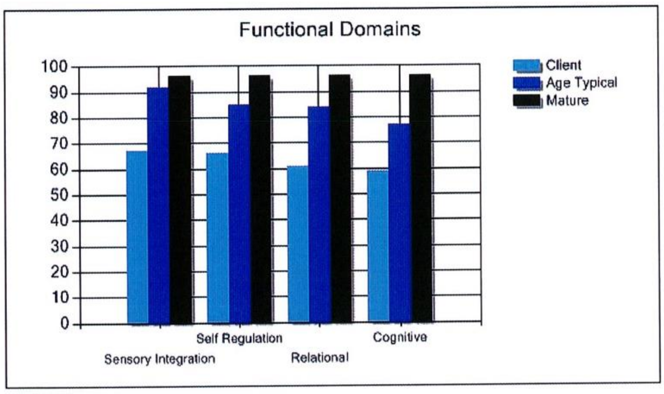


Figure 6.1 *Printed with permission from NMT ChildTrauma Academy*

Figure 6. 2 Functional status in comparison to age-typical peers: Learner A



Functional Domains Values

	Client Age	Age Typical	Mature	% Age Typical
Sensory Integration	67	92	96	72.83
Self Regulation	66	85	96	77.65
Relational	61	84	96	72.62
Cognitive	59	77	96	76.62
Cortical Modulation Ratio	1.79	7.00	24.00	25.59

Figure 6.2 *Printed with permission from NMT ChildTrauma Academy*

6.3.1.3 Data from ALSUP (present challenges)

The highlighted areas in Table 6.3 summarise the key challenges for Learner A at present. These correspond with "often" and "very often" categories on the Likert Scale format.

Table 6.3 Present challenges for Learner A as per ALSUP

ALSUP: Lagging skills
1. Difficulty handling transitions, shifting from one mindset or task to another. 2. Difficulty doing things in a logical sequence or prescribed order. 3. Difficulty persisting on challenging or tedious tasks . 4. Poor sense of time. 5. Difficulty reflecting on multiple thoughts or ideas simultaneously. 6. Difficulty maintaining focus. 7. Difficulty considering the likely outcomes or consequences of actions (impulsive). 8. Difficulty considering a range of solutions to a problem. 9. Difficulty expressing concerns, needs, or thoughts in words. 10. Difficulty understanding what is being said. 11. Difficulty managing emotional response to frustration so as to think rationally. 12. Chronic irritability and/or anxiety significantly impede capacity for problem-solving or heighten frustration. 13. Difficulty seeing the "grays"/concrete, literal, black-and-white, thinking. 14. Difficulty deviating from rules, routine. 15. Difficulty handling unpredictability, ambiguity, uncertainty, novelty. 16. Difficulty shifting from original idea, plan, or solution. 17. Difficulty taking into account situational factors that would suggest the need to adjust a plan of action. 18. Inflexible, inaccurate interpretations/cognitive distortions or biases (e.g., "Everyone's out to get me," "Nobody likes me," "You always blame me, "It's not fair," "I'm stupid").

ALSUP: Lagging skills
19. Difficulty attending to or accurately interpreting social cues/poor perception of social nuances. 20. Difficulty starting conversations, entering groups, connecting with people/lacking other basic social skills. 21. Difficulty seeking attention in appropriate ways. 22. Difficulty appreciating how his/her behavior is affecting other people 23. Difficulty empathizing with others, appreciating another person's perspective or point of view. 24. Difficulty appreciating how s/he is coming across or being perceived by other. 25. Sensory-motor difficulties.
ALSUP: Unresolved problems
1. Shifting from one specific task to another. 2. Getting started on/completing class assignments. (Difficulty entering into tasks) 3. Interactions with a particular classmate/teacher. (Often bullied by peers) 4. Behavior in hallway/at recess/in cafeteria/on school bus/waiting in line. (Supervised in library during recess for safety). 5. Talking at appropriate times. (Will talk at length without allowing others into the conversation). 6. Academic tasks/demands, e.g., writing assignments. (Dislikes writing and finds spelling challenging). 7. Handling disappointment/losing at a game/not coming in first/not being first in line.

Table 6.3 Printed with Permission Lives In the Balance

6.2.1.4 Summary of Learner A's main characteristics

Learner A's characteristics are well captured in his middle school EAP goals. He has the long term goal of becoming more aware of other people's needs so that he can develop the capacity to have friends, learn to share, and enjoy doing things together. It is suggested that he needs a lot of group participation to learn how to interact with others and not just focus on his own needs and wants at the time. His strengths are listed as a pupil who tries to be cooperative, has academic expectations for himself, enjoys computers and information technology, is beginning to develop peer relationships in his small group setting, and is pleasant and attempts be friendly. In short, Learner A is task-oriented, but he finds human interactions more difficult to manage.

6.2.2 EASTER EGG HUNT

6.2.2.1 Learner A's characteristics

In this section I discuss the characteristics that Learner A displayed during the Easter Egg Hunt cycle:

- **Session 1:** Learner A contributed to the group discussions. He chose to work on the actual location that is the school grounds.
- **Session 2:** Learner A was able to relate to me as the teacher and the dominant group member, yet he made little attempt to initiate contact with the other member in his team, who happened to be Learner B. For example, during this session he spoke 29 times in the 18 minute slot. The vocalisations were all directed at me as the teacher, except for one occasion when he spoke directly to his partner. This happened when I left the room to fetch some tissues. At this time, he shared with his partner why he thought the garden would be a good spot. Although he occasionally glanced over to see what his partner was writing in her book, he preferred working independently. For example, he requested to work separately, have his own location for the treasure, and had to be reminded to share his ideas with the group, which he did. However, in spite of the reminder he just got up and left when he felt that his work was done. Whenever I made a suggestion, he made a counter suggestion. During the session he sat parallel to and slightly rigid next to his partner and did not adjust his body to include others into his body language. Below I give attention to his request to work alone, and my reminder to him to share his ideas with the others in his group.
    - **Request to work alone:**

      Learner A: *What about me choosing one location and Learner B choosing the other location?*

    - **In need of reminders to share work:**

      Learner A: *[standing up, pushing his chair in, gathering his books, and getting ready to leave]*

      Teacher: *So you are ready for tomorrow.*

      Learner A: *Yes!*

      Teacher: *Before you go, you need to share your idea with Learner B and* *get her feedback on it. You also need to listen to Learner B's idea and give your input on it.*

[after he shared his ideas]

Teacher: *Now Learner B before Learner A leaves, you need to share your ideas with him.*

- **Session 3:** He changed his posture for this session by being more open, sitting at the corner, yet turned in facing the others. During this session he bantered with a friend on two very short occasions, but he did not pick up on it when the friend bantered back. In addition, he did not want his peers to use his ideas.
  - **Reluctant to share his ideas:**

Learner A: *What...I am saying turn 90 degrees once you are out of the building.*

Peer: *Walk out of the class. Turn. What does that say? Learner A, you started reading mine so now I am reading yours.*

Learner A: *It's mine! [sounds upset]*

Teacher: *We are a team.*

- **Session 4:** He did not seek group input when he had the choice, for example, on Day 4 during the setup. Instead, he went to sit at his desk and worked for lengthy periods on his own, setting up the clues for the other teams. At one point he left his desk and hurried over to make sure that no-one was using his iPad to access *Google Earth*, and on another occasion he spontaneously helped a peer set up *Google Earth.* On balance, he was victimised more often than the other learners, for example, on one occasion he was teased by a learner and on a later occasion he was pushed off his chair by another.

Learner A's strengths and weaknesses during the Easter Egg Hunt, and the support he received in this regard, are summarised below in Table 6.4.

Table 6.4 Strengths and vulnerabilities of Learner A during the Easter Egg Hunt

	Strengths	**Vulnerabilities**	**Support given**

<table>
<tr><th></th><th>Strengths</th><th>Vulnerabilities</th><th>Support given</th></tr>
<tr><td>Day 2:</td><td>Task-oriented
Expressive, spoke a lot
Requested to work independently</td><td>Body language rigid
Shared his idea without inquiring into those of others
Left the room as soon as his task was completed
Would reject suggestions, and propose a counter suggestion each time</td><td rowspan="3">Teacher joined as dominant group member
Redirected his ideas back to his peer, "Let's ask her what she thinks of your idea"
For example, called him back when he left, and asked him to share his idea with his partner and listen to her idea
As group member, I was also able to buffer him when he became the target of group teasing</td></tr>
<tr><td>Day 3:</td><td>Body language changed - different angle, more open and relaxed</td><td>Did not want peer to use his ideas
Complained of a headache
Sworn at by peer</td></tr>
<tr><td>Day 4:</td><td>Worked well independently
Helped a peer setup technology</td><td>Became anxious at the thought of others using his school iPad
Was pushed and teased by a peer</td></tr>
<tr><td colspan="4">Main characteristic: Exclusive:
Independent work
Emphasis on own location, own ideas, working at own desk</td></tr>
</table>

Table 6.4

6.2.2.2 Learner A's processes

In the next section, I consider Learner A's cognitive functions in relation to Feuerstein's theory and, specifically, cognitive functions from the Elaboration Phase.

i) Assessment

Learner A understood the challenge (problem definition) and showed evidence of an internal motivation to look for a solution. He was able to work with relevant cues, but not spontaneously engage in comparative behaviour. However, he could do so when prompted. In the challenge, he pursued logical evidence, produced inferentialhypothetical thinking, showed planning behaviour, and he used and mobilised mathematical terminology. The cognitive function I selected for this study from Feuerstein's list, and how these were demonstrated in Learner A, are found in Table 6.5.

Table 6.5 Cognitive functions from the Elaboration Phase: Learner A

Cognitive Function (Independent or Emerging)		**Evidence**
Search for relevant cues	**I**	He identified and worked with ideas that were relevant to the problem.
Spontaneous need to compare		Learner A tended to settle on one option from the start, the garden, instead of comparing options. He did compare options when asked to, but it was not spontaneous.
Use of logical evidence	**I**	Teacher: *Have a bit of a think. So we want to plan this treasure hunt. You decided that the library is a really good spot.* Learner A: *I said garden. I do think the library is a good spot. It is inside and the eggs won't melt. But there is not much space to hide, just bean bags. And they can crack the eggs.*
Abstract thinking	**I**	Learner A was able to see the treasure hunt "in his mind's eye". He drew the map and explained his route to the treasure from his desk.
Make a plan - think forward	**I**	Teacher: *How are we going to do this?* Learner A: *How about - we need to leave clues. We need to say go to this place and find the next clue.* Teacher: *So you want to make clues?* Learner A: *Yes, we can stick them to the walls. The first one can be down the hall here. They can read it. The next one can be in the science room. No, not in the science room but in the hall next to the science room where you can see it.*

Table 6.5

ii) Mediation

I assessed Learner A by asking him questions, and noted that Learner A was able to develop his ideas independently. Right from the start Learner A indicated that he wanted to place the treasure in the garden, near the scarecrow. To see if he could produce multiple options in addition to his own idea, I asked him to brainstorm with me and his partner. Whenever I made a suggestion, he matched these with counter solutions. On the one hand, this was positive as it showed that he could give an opinion, form his own judgement, and provide alternatives. On the other hand, I was unsure if it was a form of control, meaning an inability to negotiate or see another perspective. Based on Learner A's strengths, I argued that he needed extension more than intervention. For this reason, I first challenged him to work with distance, which he dismissed. His argument was that it would be too hard for his peers, and that we should focus on making it easier for them, and not harder by adding distance.

- **Not wanting to extend into distance:**

  Teacher: *Now the clues need to be full of directional words. For example, take 20 steps forward…take 6 steps to the left.*

  Learner A: *I was thinking of, well some learners don't know the school well, they might need some help, so they need more clues to realise where they are going. We need to make it a little bit easier for some people. So that they can do really well.*

However, as I was talking his partner through mathematics language options, he became interested in degrees and started developing this in his work.

- **First attempt:**

Learner A: *Walk out the building. Walk straight. Miss, so the next one is going to be walking out the building, go to the science room.*

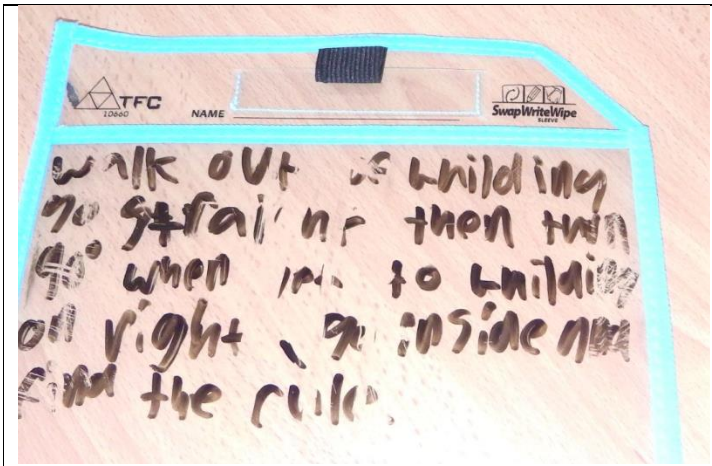
- **Mediation:** Reminder of the learning task criteria (on the board).

Teacher: *As I just said to Peer, you need to use words like left and right, backwards, 90 degrees. I want you to use directional* *words. So, leave the classroom, turn right, walk straight to the door. Turn left. That kind of language.*

Learner A: *Can I have a rubber please?*

He was independent in setting up his rules and hiding his treasure marker, in that he only asked me for a list of stationery materials. More examples of Learner A's work is found in Table 6.6, which show his planning and use of mathematical language.

Table 6.6 Examples of Learner A's representations

	*Walk out of building. Go straight then turn 90 degrees when you see the building on right. Go inside and find the rule.* These representations were photographed after the treasure hunt, so they are a blurred on the photo. Altogether he produced 6 different "rules".

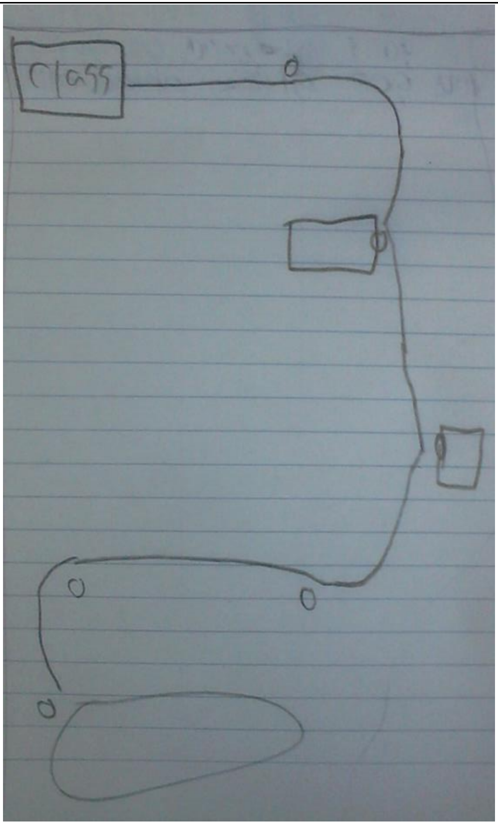
	The circle shows where he plans to put the clues.

Table 6.6

6.2.3 DEFUSE THE BOMB

6.2.3.1 Learner A's characteristics

- **Session 1:** Learner A worked intently on the task from the start. He paid attention to the explanation I gave on how the rotors had to line up to defuse the bomb. Thereafter, he got so involved in trying to solve the problem that he paid no attention to anyone else, including his partner. I went over there to remind him to work with his partner and to give her a turn as well. He then shared with his partner, assuming the role of scribe while his partner tried to work out the combination and the turns. He did this for a while before returning to handling the device himself again.

- **Session 2**: Due to the teasing incident the day before, I swapped partners around, which meant that Learner A had a new partner, who happened to be Learner B. Learner A called her over, prepared a chair for her, gave her the pen, prepared the bomb by setting the rotors to starting position. He stopped her and encouraged her when she hesitated, all in a calm and gentle manner.

- **Encouraging his partner**

Learner B: *Stop*

Learner A: *Are you sure?*

Learner A: *So five, clockwise, 1 ½ turns.*

Learner B: *Five..?*

Learner A: *So its five, clockwise, 1 ½ turns – so you do another 1 and then ½ like that one.*

Learner B *[rubs out Learner A's work]. So you do a little one – like that [points to previous one]. Like that, but not with that number.*

Learner A: *Like that.*

[Learner A gets up, rubs Learner B's work out and writes the number in]

Learner A: *1 and ½ - like that!*

Learner A: *[points to the other half on the table] Like that!*

- **Session 3:** When a member for the other group came to sit at Learner A's table to defuse the bomb, by using their directions, he got up and moved around, first to one side of the room, then back to the table, then to the other side of the table. His partner was unsure how to read fractions such as ¾. When she became silent in reading out the direction, he filled her in. At one point, the learner following the directions stopped, asking "What does that mean?", referring to 1 ¾. Learner A explained that he had to break it up into a "full turn, and then a ¾ turn" following on from there.

I picked up that the directions given by Learner A's group were not accurate, for example, that the group wrote 1 ½ turns when it was actually over ½ and more towards 1 ¾ turns on the dial. I tried to draw attention to that through questioning Learner A on the numbers of the dial and by asking him to illustrate the turn from one number to the next for me. After he illustrated it, he realised his error and made the corrections.

When the other group's member could not defuse the bomb by using the directions provided, Learner A looked at the person turning the dial and said, "You've got it mixed up". That may be true, or not, but Learner A did not closely monitor the actions of the other learner as he turned the dial, and therefore did not have any evidence to back up his claim. Thereafter, Learner A said, "Miss, we are going to start again from the beginning.", and started working on the project again.

Table 6.7 provides a summary of Learner A's strengths and vulnerabilities during the study and draws attention to the support that was given to him.

Table 6.7 Strengths and vulnerabilities of Learner A during the Defuse the Bomb Challenge

	Strengths	**Vulnerabilities**	**Support given**
Day 1:	He was searching for a solution.	Ignored his partner.	Reminded him that he had to work with his partner. Asked all learners to share the device with their partners after a set time.

	Strengths	**Vulnerabilities**	**Support given**
Day 2:	He collaborated with his new partner. He was inviting, offering her a chair and a pen, asked her to come closer so that she could she see, encouraged her, and fixed her mistakes.	Told his partner what to do, without explaining it to her. Rubbing her work out and writing the correct version over it, without explaining.	Reminded him to ask for his partner's input and to check in with her before making final decisions
Day 3:	He persevered over three days until he had the code. He helped some of the other learners with making mixed fraction turns, and with reading and writing the symbolism	Assumed the partner from another team got directions wrong, but was willing to have another go at checking his own work.	Suggested that he confirms the accuracy of a certain section of his work.
Main characteristic: Autocratic: • Inclusive on own terms • A bit bossy by telling his partner what to do • Delegating on own terms			

Table 6.7

6.2.3.2 Learner A's processes

In the next section, I consider Learner A's cognitive functions in relation to Feuerstein's theory, and, specifically, cognitive functions from the Input Phase.

i) Assessment

Table 6.8 shows which of Learner A's cognitive functions were strong and which ones were still emerging, and provide evidence for these evaluations. During this challenge, Learner A was developing his ability to collate multiple sources of information and to record these accurately.

Table 6.8 Cognitive functions from the Input Phase: Learner A

Cognitive Function (Independent or Emerging)		**Evidence**
Focus and Perceive:	**I**	He looked intently at the dials, the rotors and how they affect one another.
Systematic Search:	**I**	He realised that his plan was missing something (aligning the rotors from the back) and adjusted it accordingly.
Know where you are in space (clockwise, anticlockwise):	**I**	Teacher: *Do you know clockwise and anticlockwise?* Learner A: *Yeah! Anti-clockwise is backwards; and clockwise is forwards.* Teacher: *Which way is your partner turning the dial?* Learner A: *Clockwise.* Teacher: *Yes.*
Be aware of time (how much, how often, sequence):	**I**	He could keep track of the turns e.g. 2¼ turns. He understood that he made two full turns and then a quarter.
Conserve constancies	**I**	He could identify fractions from many different starting points on the dial. He indicated that it was 2 ½ turns when it was 2 ¾ turns, but this is most likely an issue of accuracy and not conservancy.
Collect precise and accurate data:	**E**	His first attempt was precise, but he did not keep track of the data.
Use more than one source of information (turn, direction, distance):	**E**	He started working with one source of information, aligning the rotors, without recording the number on the dial, or the turns, or the direction of the turns.

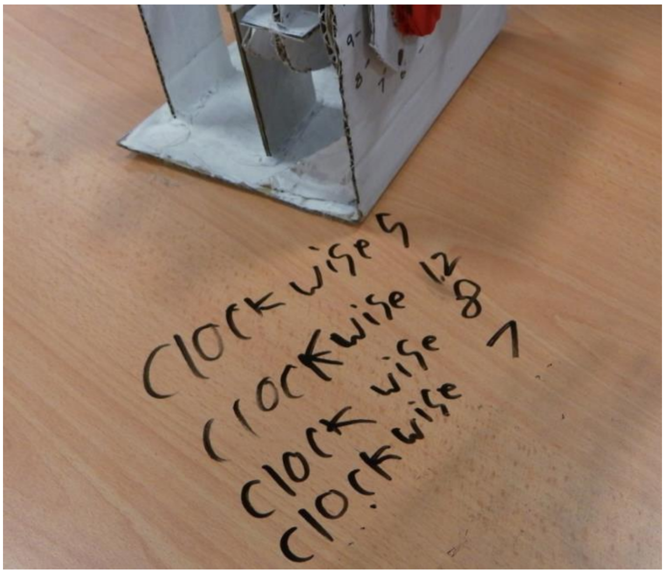
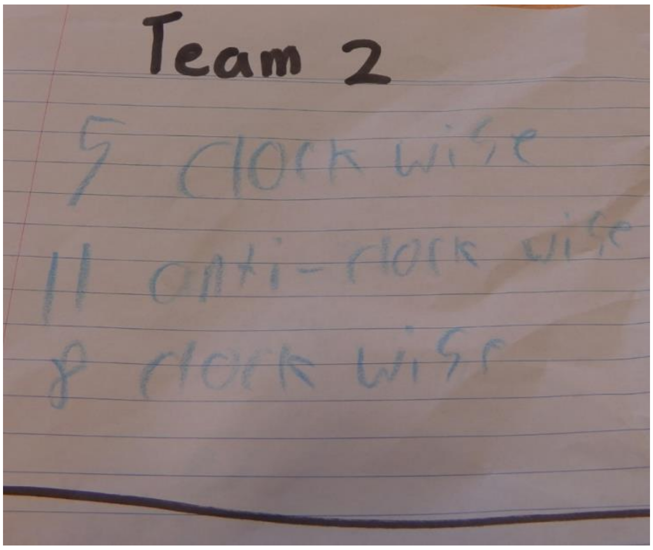
Table 6.8

ii) Mediation

In Table 6.9, I show how I mediated Learner A's cognitive functions during the *Defuse the Bomb Challenge*.

Table 6.9 Mediation: Learner A

First Attempt: Learner A: *Miss, I defused it.* Teacher: *Great, so what is the code?* Learner A. *mmm* *[silence]* Teacher: *Start again. You have to produce the code and the directions.*	First mediation: I reminded him of the task criteria, which were on the board.
Second Attempt: Learner A: *Miss, I didn't get it. I didn't get (anxious).* Teacher: *That's ok. What can you do differently this time to defuse the bomb?* Learner A: *(silence)* Teacher: *I just remembered. I forgot to tell the class that the rotors have to line up from the back. Try and get the back one in line first, then work from there.*	Second mediation: I realised that I had not informed the learners that the rotors had to line up from the back to reduce overload. Seeing that I did not want the learners to get caught up in the mechanism of the design, but in the mathematics aspect, I told him where he was going wrong.

<table>
<tr><td>
</td><td></td></tr>
<tr><td>Third attempt:

</td><td>Third mediation: I reminded him of the task criteria, which were on the board.</td></tr>
<tr><td>Fourth attempt:</td><td>Fourth Mediation: His directions were tested by other group. The other group, however, did not pick up the error, as they were absorbed in trying to follow the correct number of turns. My intervention was to ask him to check the turn from 5 to 11, and confirm his answer. He realised</td></tr>
</table>

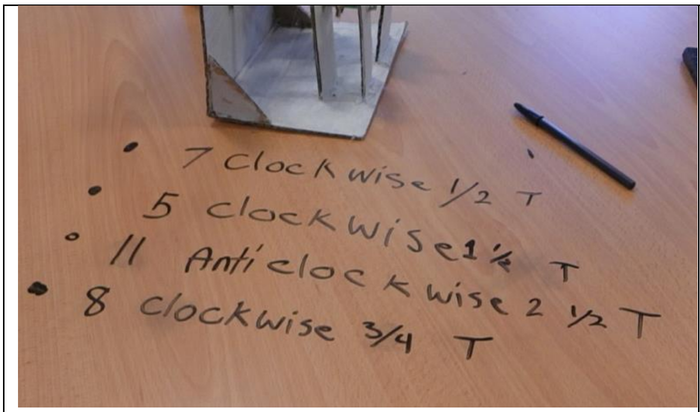
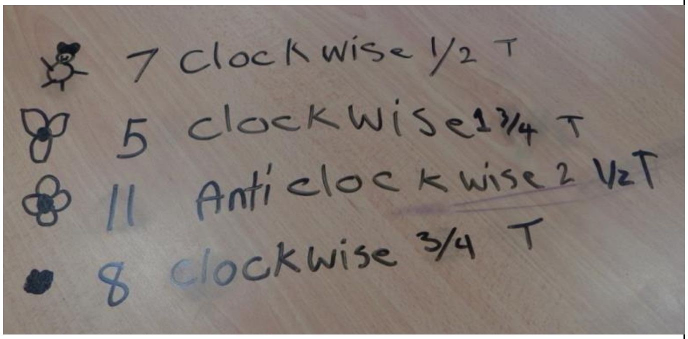
	that it was more than ½.
Fifth and final attempt: 	The attempt before his final attempt was very similar, except that he made the error of 1 ½ turns, which he corrected and changed to 1 ¾ turns.

Table 6.9

6.2.4 FLY THE HELICOPTER

6.2.4.1 Learner A's characteristics

In this section I discuss the characteristics that Learner A displayed during the *Fly the Helicopter Challenge*.

- **Session 1: Building blocks**

Learner A made a noticeable attempt at the start to involve the group by telling the others that he was going to start building the school with two specific blocks. No one in the group responded. Instead, they seemed to take no notice and kept working parallel, playing with the blocks. However, after the incident where the learners threw blocks at one another, and I reprimanded them, he seemed more anxious. He became lost in the task, ignoring the others in the team except for his peer who was passing the blocks to him, and he rushed through the activity. It was around this time that I asked the group to reconsider if they were really working as a group. Shortly thereafter, Learner A couldn't find a particular shape and colour of block, and a team member proposed an alternative solution. After this his language changed from "I am making…", which he used previously, to "We made…"

- Incorporating another team member's suggestion

Peer: *Just take these two out. Look! (leaning over to touch the blocks)*

Learner A: *Wait!! (covering his hands over the blocks)*

Peer: *And put these two in.*

Learner A: *Ah true! (he removes his hands and lets the other peer in to touch the blocks)*

Learner A: *It is too… Wait a minute...[takes another shape and fits it in]*

Learner A: *Miss, we just made the Year 9 block! Miss, look, we just made the Year 9 block!*

- **Session 2 and 3: Learning how to draw 3D shapes and top view**

Learner A watched the video with the class that was describing top view and how to derive it from a 3D figure. At the very start of the video he played with the speaker, holding it to his ears, and tracing its corners. After a short while, he let go of the speaker and followed the video. While the video was playing and the 3D drawing was taking shape, he made comments such as "*Wow, I can see it already!*" and later on, *"This is awesome!"*

When he had to start drawing, his iPad was offline. While trying to get his iPad to work, a peer was playing with the projector, blocking its light with a paper. He asked her to stop as he couldn't concentrate, and he sounded annoyed. As I moved around the class, he reminded me on three occasions that his iPad was not working. I asked him to try on his computer instead of on his iPad. As he was seated near the projector equipment, I asked him to replay the video for another learner a bit later on.

- **Difficulty transitioning from his computer problem to helping a peer**

Teacher: *Learner B, could you look at the video again? Learner A, could you play the video again for Learner B.*

Learner A: *What Miss? What? What do you mean by playing it again? We already saw it.*

Peer: *Maybe play it again. On Youtube.*

Learner A: *Miss, what do you mean by like, show it again?*

Teacher: *The video, Learner B needs to see what top view is.*

Learner A: *Aaaahh! Fine!*

Learner A: *Learner B, look that is top view. That is top view. That and that. All you need is just to know what it is.*

The peer who needed help moved into his space, but he took no notice of her and carried on trying to get his equipment to work. A little while later he leaned over, watched her draw on her iPad for a few seconds, and then went straight back to his computer, turning his body away from her and shifting along the table away from her. He eventually gave up on trying to draw on the computer, saying it was too hard. At this point his peers starting teasing him, calling him dumb. After a while, his iPad connected and he left the table and went to sit quietly by himself on the couch and worked. When he was finished, he called me over to come and see, *"Wow, Wow, look, look at this...3D"*.

The video continued the next day, and learners had to draw a top view of the school, as seen from *Google Earth*, which he did. Afterwards, he talked me through the buildings as he saw them. He made no corrections, and his drawing had no labels.

- **Session 4: Minecraft**

During this activity Learner A's conversation was mostly parallel, following a show and tell theme. At one stage, he acknowledged another person's work, which inspired this particular peer to do more work. Later on Learner A accepted correction from a partner who noticed that he did not tuck his bleed lines in.

- **Appreciation of another learner's work:**

Learner A: *Hey Miss, Look! I made the top of the chest. Look!*

Learner C: *Look what I just made.*

Learner A: *aaaaaahhhhhh! [appreciation and interest]*

Learner C: *I will do this one for you. I will do this one for you. [speaking to Learner A]*

- **Correction by a peer:**

Peer: *You have to tuck it in.*

Learner A: *You mean like that.*

Peer: *No…You have to tuck it in. You will need to pull it all out.*

- **Session 5: Choosing a drawing from all the drawings**

Learner A was one of two learners in the class who was able to establish more objective criteria in terms of comparing the drawing to the model, in contrast to learners who adopted only a subjective approach based on personal like or dislike, or on superficial criteria, such as dark smudges around the outside of the paper from the photocopier. He was questioning the criteria of his peer saying that she needed to develop more clarity around her reason for selecting a particular drawing. At one stage, he pointed out to the class which drawing was his, and thereafter certain learners starting teasing him by making inappropriate comments about his drawing.

- **Challenging his partner's view:**

Teacher:	*You need to look at the drawings. Decide which one to use and why? Which of these is the best - the one we should use? Give me three reasons?*
Learner A:	*I think this one is the best. I think this looks awesome. And it is someone else's. It is not mine.*
Learner B:	*I think this one.*
Learner A:	*I don't. What's that? Look! What is that connected to? It is not connected to anything. There is no connection. This one has darker edges, but this one has lighter edges here.*
Learner B:	*It looks the same.*
Learner A:	*Now look at this one here. It is not really the same. Some areas look the same as the picture. Some areas like THAT, THAT, THAT and THAT. Some areas look the same as the picture. That is a good reason.*
Learner B:	*What else?*

- **Session 6: Measurement**

The idea was to look at one block on the graph paper and to associate that with a measurement related to the measuring wheel, for example, one block = 1 metre. However, the learners spontaneously started measuring. I called Learner A aside and reminded him verbally that he needed to work with the group. After this, he became the tutor, he assigned different tasks to different learners, and kept them on-task.

- **Peer tutoring:**

Learner B: *You mean the thing. Here.*

Learner A: *That little thing. This square here. Right there.*

Learner B: *Four… Five… Four*

Learner A: *Wait, you have to start at zero.*

Learner B: *There... That is zero right there.*

Learner A: *That is zero there. No.*

Learner B: *Ah... That is zero...*

Learner A: *Zero...*

Learner B: *How about three... is it three?*

Learner A: *Write it down on paper.*

- **Role assigner - keeping learners on task:**

Learner B: *Hey, let Peer do some? Hey Peer, do you want to measure? What about you do this, Peer, this block right? Can you do that? And I do this one here?*

Learner A: *Since you are doing that, that means Peer can do our area. Is everyone good? And shall I do the Year 9, the Year 7 area, and staff room… front office? Ah... Learner B... hello..!*

Learner B: *Our area.*

Learner A: *Peer is doing this area right…*

Learner B: *What about Peer doing this square thing? I wish I could do our area.*

Learner A: *No, she is doing our area. I just talked to Peer and I told her if she wants to do it and she said yes. She will do the canteen side and area. The area I've got to do is the Year 9, Year 7, and staff room area and the front office. That's that. What you got to do is just this area… That's it. And you are good. And use a ruler and measure how much the lines are on the paper... where the line is… see… and write it down here. You may want to put it where the line is…*

- **Mentor and Encourager**

Learner A [to peer]:

Are you still going all right with that? Are you going to try our area? You want to start? When you do… that line, that line, that line and that line. And then if you want to do extra you do that area there, that line, that line, that line, if you want to do extra. If you want to actually that's it. That is it. That is all you need to do. It is easy.

Learner A [to teacher]:

I am just explaining to her what she can do. I am probably going to leave this area, this in case she wants to do extra. You see, you've got that bit. You measure it down. You look where zero is. Zero is right there. And then you go along. As we said yesterday, when it is closest to the nine here, you just put to nine and then you go to that one, and this line because these lines are the same… down there and it looks like that, it looks like 3 cm is close, and then write it down and you are good. It is ABC, 1-2-3. That's it. Straight. On the line.

And this line… Start again. One, Two Down. There it is.

Teacher: *Did you get information from both your partners?*

Learner A: *Yeah… Hmm. That is from Group Member and that is from Learner B, and that is from me.*

- **Error-checking**

Teacher: *Did you and Peer compare your work? It is always good to measure your accuracy against your partner's work. Tell Peer then, look we got the same here.*

Learner A: *6.5 and 7...*

Teacher: *I am happy with that – they are close enough.*

Learner A: *That's right… 10 cm that is right… That is more than 9.*

Learner A: *[compares his own work to Learner B's work]*

Learner A: *4 cm… Yeah that is good. 3 cm... Yes that is good. 2.5 …12 cm… Yip that is good. Learner B's is all good and really good. It's good. Is it good, Peer?*

- **Session 7: Scaling on the oval**

He participated in the class discussion by answering some of the questions in a chorus-like fashion together with the other learners. Additionally, he gave suggestions when the measuring wheel got stuck, watched and encouraged his peer who was measuring the room, and told him when to stop the wheel at the right point. In his discussion, he used ordinary language, not mathematical language, for example, he spoke of sides and not length and width.

Once on the oval, Learner A took the wheel and rolled it along one of the oval's painted lines. Thereafter, he walked back to me, asking, "What should we do now?". Once I explained, he called his partner, and he pushed the wheel while his partner counted out loud next to him. He waited for his partner, who was busy with the tape. After a while, he called her but she took no notice. Later on, Learner C came around and started wrapping him up in tape. He screamed, telling Learner C to stop doing that and to let him go. He did not want to be part of the game and seemed anxious at the prospect. Whenever the learners ran up to him to wrap him up, he would yell at them in a distressed manner to let him go. To get away from his peers, he came to stand next to me, saying, "I don't know what to do. I don't know what to do. I don't know what to do.".

- **Session 8: Scaling in the classroom**

Learner A worked hard with his team, which included Learner B and another group member. This particular group member in his team, who he is addressing (see below), is by nature very anxious, shy and needs a lot of encouragement, and the conversation shows how he adjusted his own approach to include her into the activity.

  - **Adjusting his tone to include a more vulnerable member**

Learner A: *Ready. Come on Peer, are you going to help? Ready… go. 1 metre, 2 metre, stop, back a little, back a little, stop. There you go. That is a whole 3 metre. So now, [Learner A draws line], now, what are you doing, just 1 metre? Peer, are you going to do the chalk? Are you going to do the chalk? Just 1 metre. That's it... Stop. Now what are you going to do… Do one whole line? You want to do that… Come Group Member… Ready… Go… 1, 2, 3 stop… a line… There we go. Let's give Peer the last one. Here, Peer, you do the last one. 1 metre… there you go… stop… mark it. Here we go...*

there. [Looking at the drawing].

- **Session 9: Designing the grid reference and flying the helicopter**

Learner A seemed confident in creating grid references and in assigning coordinates to buildings. At the same time, he noticed that Learner B was not constructing a grid reference and he used his completed grid reference to explain the idea to her. Thereafter, he made an attempt to fly the helicopter, but gave up quite quickly after crashing it into the ceiling a number of times.

Table 6.10 provides a summary of the learning characteristics of Learner A during this modelling cycle.

Table 6.10 Strengths and vulnerabilities of Learner A during the Fly the Helicopter Challenge

	Strengths	**Vulnerabilities**	**Support given**
Session 1: (Blocks)	He was very task oriented He moved from blocking input from his peer to incorporating it into his solution	Controlled the blocks Took Learner B's blocks away when she disagreed with him on the size. She was upset and tearful Loss in knowledge - some learners in group did not want to contribute their knowledge, as they did not want to upset him	I provided general clues to the group to work as a team. During the learner focus group that week I spoke about the need to assign roles in groups and to be careful not to dominate
Session 2 and 3: (3D drawing and top view)	His drawings showed strong elements of precision and an effort to be accurate	Had difficulty transitioning between his computer problems and assisting a peer. Was reluctant and a bit abrupt	I asked him to be a peer tutor to a peer

	Strengths	Vulnerabilities	Support given
Session 4: Minecraft	Showed appreciation for a peer's work which encouraged the peer to continue Accepted correction from another peer		None
Session 5: Choosing a top view	He was able to work with relevant criteria in justifying his decisions. He questioned his partner and the other group to provide deeper forms of justification	We agreed as a class that we would keep the drawings anonymous. Yet, he wanted others to know which paper was his, and that led to him being teased and his work rejected by his peers. The other group got upset with him when he questioned their reasoning	I reminded the class of our school values and the need to show respect to one another.
Session 6: Measurement	Assumed different roles - tutor, encourager, checking work		He was reminded to work with his group
Session 7: Scaling on the oval	Tried to work with his partner and continue with the task in spite of the conditions	Became anxious when learners abandoned the mathematics project and started a game	He came to stand next to me when the learners started playing
Session 8: Scaling inside			A reminder before the group started that they needed to work as a team
Session 9: Designing a grid and flying the helicopter	He was confident in creating a design grid and in providing coordinates	He gave up fairly quickly when he could not control the helicopter and crashed it into a table	None
Main characteristic: Democratic Inclusive • Becoming a mentor, peer tutor • Still delegating, but more willing to consult			

Table 6.10

6.2.4.2 Learner A's processes and representations

Table 6.11 shows which of Learner A's cognitive functions were strong and which ones were still emerging and provides evidence for these evaluations. Noticeably, more of Learner A's cognitive functions were underdeveloped in the Output Area, compared to the other cognitive functions of the other two phases.

Table 6.11 Cognitive functions from the Output Phase: Learner A

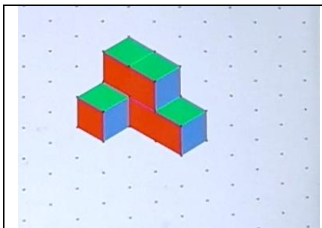
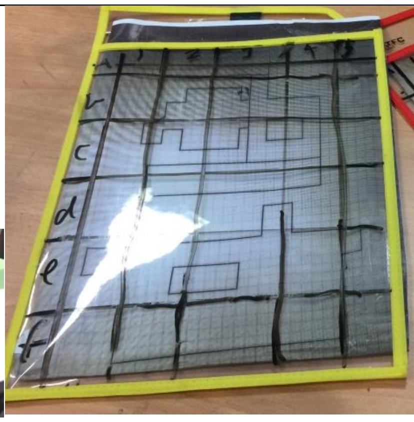
Cognitive Function (Independent or Emerging)		**Evidence**
Considering another person's point of view	**E**	At times he had real challenges with understanding how his actions were affecting those around him. For example, his peer was very upset when he took her blocks away when she refused to do so herself.
Visual transporting (copying accurately from the board or other source)	**I**	His drawings and buildings (from the blocks) were reasonably accurate.
Perseverance	**E**	He did not give up on any of the maths tasks, but he gave up on trying to fly the helicopter after his second attempt.
Communicating clearly with right vocabulary	**E**	He was able to communicate his ideas to others, but his vocabulary was vague (both mathematically and generally), for example, he used terms such as this and that instead of the names of the buildings, and language such as sides instead of length and width.
Just a moment, let me think (avoiding trial and error responses)	I	He made an effort to first consult his drawing, and to work closely with his drawing while scaling. He also adjusted the scale by himself after the oval, for use in the classroom.
Use precision and accuracy	**I**	He was making an attempt to be precise and accurate

Cognitive Function (Independent or Emerging)		**Evidence**
Show self-control (don't panic or fret when you don't know)	**E**	He was more vulnerable in this area. For example, on the oval when the learners started playing chase, he became very anxious and unsettled. He also showed anxiety when he couldn't fly the helicopter but crashed it into the table.

Table 6.11

In Table 6.12, I include some of Learner A's representations from the last mathematical challenge, showing evidence of his visual transporting and precision and accuracy skills.

Table 6.12 Learner A's representations from the Fly the Helicopter Challenge

 Learner A's drawing matched the tutorial's one. 	 Learner A's grid reference

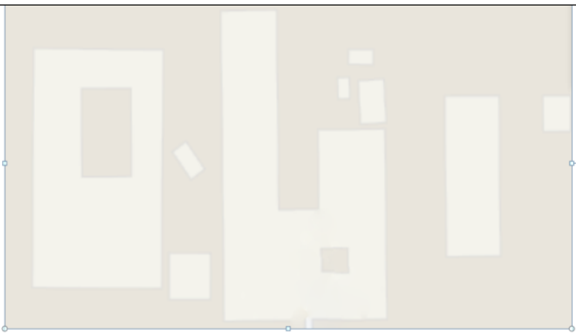
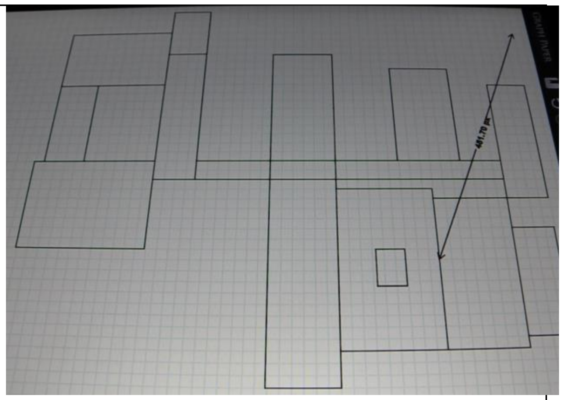
 This is the correct version. Learners however did not copy this, but the actual image of the school as seen from *Google Earth.* To protect the anonymity of the school I did not include the actual image from *Google Earth* in this dissertation.	
Overall Learner A's visual transporting and precision and accuracy seem to be reasonably strong.	
	
Mediation: I asked Learner A's group to go back and label their work.	

Table 6.12

6.2.5 RESEARCH QUESTIONS: LEARNER A

6.2.5.1 What is the relation (if any) between the learning behaviours during mathematical modelling and the pscyho-educational profile?

One of Learner A's main challenges, as seen in his psycho-educational profile, was his social skills. He has difficulty negotiating social situations and social interactions. What has this got to do with the learning of mathematics? In Learner A's case, a significant amount. His NAPLAN results in Year 6 indicated that he was achieving mathematics at year level, yet he was placed in a special education centre because of social behaviours. Yet at the beginning of his Year 8 year, when he was tested using OnDemand, his scored indicated that he was at a Year 3-4 level. There are different scenarios that we can assume to explain his drop. One relates to the redundant SEN curriculum, in that he has not been exposed to challenging mathematics for over a year which made his scores drop. Alternatively, there is test anxiety. After the research, I asked him to complete a PATtest at a year 4 level. He rushed through the test, making many mistakes. Noticing this, I went to sit next to him and said, "Take your time. Have a think." After that he got every problem right. On the whole, special education centres offer redundant mathematics curricula, which means that the longer he attends a special needs environment, the more of mainstream concepts he will lose out on and the harder it will become for him to catch up later on. To summarise, his social skills are what is keeping him from mainstream mathematics.

The data indicate a development of Learner A in terms of his social skills in a group. To demonstrate, during the first challenge his behaviour was exclusive. He requested to work independently, he wanted his own treasure spot, he saw his ideas as his own and did not want to share them with others in his group, and he worked alone at his desk during the setup phase. In the second challenge, he at first got so caught up in the task that he seemed to ignore his partner altogether. He then assumed an autocratic role, where he worked with his partner but on his terms, being "bossy". It must be remembered that the group was non-threatening and that it had several parameters, which were suitable to Learner A's vulnerabilities in relation to task structure, power, and relational issues. For example, Learner A had the upper hand in terms of knowledge. He knew measurement, whereas they did not. This allowed Learner A to direct his desire to control situations in a positive manner. For example, in the last session both his partners were more subdued and relied on his manner and expertise to get them through the task. I anticipate that in mathematical learning situations that will increase anxiety in Learner A, such as mathematics problems that challenge his level of expertise or working with more knowledgeable or assertive peers than himself, he will need further support.

Another pattern that emerged in relation to Learner A's profile was that certain kinds of play produced high levels of anxiety in him. His anxiety increased when there were elements of physical play. For example, when the learners started throwing the blocks at each other, they were laughing and giggling, but Learner A ran to get me and appeared anxious at the time. When they started playing chase on the oval, he was anxious again, informing me repeatedly that he did not know what to do. He was anxious about flying the helicopter and gave up fairly quickly after he crashed. Yet, he was content creating Minecraft shapes and exploring that world with others in a more imaginative way, or building blocks, or moving around in *Google Earth*, all seemingly less physical types of play.

6.2.5.2 How did his cognitive processes influence his modelling?

Overall, Learner A had a reasonable set of independent cognitive functions. In areas where his cognitive functions were vulnerable and emergent, he mostly needed an explicit reminder of the expected outcomes, which was on the board in the form of learning criteria and success criteria. Similarly, he needed explicit statements on what was expected of him socially before the group started. His assessments showed that he needed more support in his Output phase than in his other areas. This matches his psycho-education profile, which indicates vulnerabilities in social behaviours (seeing something from another's perspective), anxiety, and communication.

6.2.5.3 What evidence of learning can be found in the analysis of learner's reasoning and representations over time?

My assessment of Learner A was that he:

- was engaged in all the tasks
- was actively involved in his own learning

- drew on a range of important mathematical concepts.
- used multiple methods of representations.
- successfully connected mathematics to the real world
- was able to use digital technology appropriately
- took ownership of his learning
- expressed a positive attitude and overall enjoyed the activities

Moreover, I assessed Learner A as using a Level 4 depth of knowledge in his models (see Table 6.13) and, according to mainstream criteria, I would place him (see Table 6.14) at a Standard 2 level in terms of problem identification and model construction, and at a Standard 1 level in the model verification area, considering his difficulties with expressing his ideas using mathematical language.

Table 6.13 Depth of Knowledge: Learner A

Level 1	**Level 2**	**Level 3**	**Level 4**
Recall a mathematical fact, term, principle, or concept Perform a routine procedure or basic computation Locate details	Use mathematical information Have conceptual knowledge Select appropriate procedures Perform two or more steps with decision points along the way Solve routine problems Organise and display	Develop a plan or sequence of steps Make decisions Justify decisions Solve problems that are abstract, complex, and non-routine More than one possible solution Support solutions and judgements with evidence	An investigation or application to the real world Non-routine problems Solve over extended time Requires multiple sources of information

Table 6.13

Table 6.14 Progression along a standard matrix: Student A

Criteria	**Standard 1**	**Standard 2**	**Standard 3**
Ability to specify problem clearly	Is able to proceed only when clues are given	Can extract clues from information and translate them into a clear expression of the problem to be solved	Is able to perform as for S2 and in addition can clarify a problem when information is open ended insufficient and redundant
Ability to formulate an appropriate model: choose variables and find relationships	Is able to proceed only when clues are provided	Is able to determine important factors and develop relationships with a minimum of assistance	Is able to determine important factors and develop relationships independently where no clues exist
Ability to solve the mathematical problem, including the mathematical solution, interpretation, validation, evaluation/refineme nt	Is able to solve the mathematical problem given substantial assistance through clues and hints	Is able to solve the basic problem with little or no assistance. Generally unable to refine the model	Is able to solve the basic problem independently. Is able to evaluate and refine the model
Ability to communicate results in a written and oral form	Is able to communicate reasonably in regard to layout (including use of visuals), presentation, conciseness, and orally with some prompting	Is able to communicate clearly with good use of aids and without prompting	Is able to communicate clearly with outstanding presentation including innovative creative features

Table 6.14

Last, Table 6.15 contains comments from Learner A regarding his modelling learning experiences:

Table 6.15 Reflections on modelling: Learner A

Easter Egg Hunt	Teacher: *What do we need to learn next?* Learner A: *Miss, not everyone understood angles. You need to teach them about angles.*
	Teacher: *How did you experience the learning task?* Learner A*: It was quite confusing to start with, but when I got it, I got it. [referring to him finding the other group's treasure on Google Earth]*
Defuse the Bomb Challenge	Learner A: *It was good. I liked working out what it was. [meaning the combination]*.
Fly the Helicopter	Teacher: *Do you feel that you learn better from one another? Or do you feel that you learn better on your own?* Learner A: *I feel I learn better from one another. It kinda helps like talking to one another.*

Table 6.15

6.3 CASE STUDY: LEARNER B

6.3.1 Psycho-educational profile of Learner B

6.3.1.1 Data from school files (chronologically)

Learner B has a history of developmental difficulties and has had considerable interventions since she was very young. She received speech pathology, occupational therapy, and physiotherapy involvement from the local Children's Development Team for speech and language delays, delayed motor development, visual perceptual difficulties, and sensory processing difficulties. An overview of the support and intervention she has received up to this point in her schooling is documented in Table 6.16.

Table 6.16 Support and intervention history of Learner B

Learner B	Event	Assessment	Results of Assessment	Support
Age 2	Seizures	Specialist at hospital	Cyst in brain stem area	Ongoing scheduled appointments to monitor growth of cyst throughout her life
		Speech Therapy	Severely delayed receptive language, expressive language and speech articulation	Speech programme
Age 3		Occupational Therapy	Fine motor skills and thinking skills were age-appropriate. She had sensory processing issues of low registration and sensory seeking	
Age 5		Speech therapy review		Speech programme for home and for school
		Cognitive assessment Kaufman Assessment Battery for Children	High levels of distractibility and short concentration span	
		Paediatric assessment	Global developmental delay	

Learner B	Event	Assessment	Results of Assessment	Support
Age 6	Started school. Difficulties included: getting started and staying on task, rocking on chair, social skills and working in groups, gross motor coordination, poor balance, fell and tripped, walked on her toes	Speech Therapy review		School and home speech programme
		Occupational Therapy review	Delayed skills in visual motor integration, fine motor coordination, visual perception, sensory motor skills, and gross motor skills	Strategies from OT to be included into her school work
		Physiotherapy	Easily distracted, tired easily, difficulty keeping eye contact, immature ball skills and balance patterns	
		Behaviour assessment Vinelands Adaptive Behaviour Scale	Adaptive behaviour in the mild deficit range	Early childhood development centre for first year
		Cognitive Assessment: Stanford-Binet Intelligence Scale: 5th edition		When she joined mainstream, she received a LSA to provide one-on-one support Modified curriculum Attended life skills sessions on a weekly basis at the special school
Age 7		Occupational therapy review	Delayed skills in visual motor integration, visual perception, fine motor coordination and sensory integration	
Age 7		Hearing test	Normal hearing	
Age 11	Tired and have mood swings from medicine. Does not want to take it	Paediatric assessment	Epilepsy (adjusted medication)	Medication for seizures

Table 6.16

6.3.1.2 Data from brain map (function and structure of brain)

Learner B's brain map can be found in Figure 6.3. The lower scores in the brain stem area are related to attention, her difficulty in staying focused on a task, and her short attention span. The lower scores in the cerebellum are related to poor co-ordination, for example, she struggles with ball skills and with clapping a rhythm. Moreover, her therapy reports indicate that she has challenges with sensory integration. Her low scores in her limbic area are related to her difficulty with seeing another person's point of view, and she has no age-typical friends. She struggles with most of the categories in the cortex, especially in the area of communication and speech. Moreover, she is well below her age-typical peers in terms her level of school work as reflected in her frontal cortex.

Figure 6. 3 Functional brain map: Learner B

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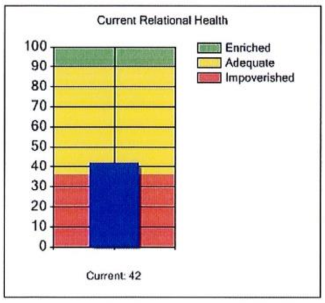
Current CNS Functionality

		Client	Typical
	Brainstem		
1	Cardiovascular/ANS	12	12
2	Autonomic Regulation	12	12
3	Temperature regulation/Metabolism	9	12
4	Extraocular Eye Movements	12	12
5	Suck/Swallow/Gag	12	12
6	Attention/Tracking	4	11
	DE/Cerebellum		
7	Feeding/Appetite	8	12
8	Sleep	9	12
9	Fine Motor Skills	9	11
10	Coordination/Large Motor Functioning	4	10
11	Dissociative Continuum	5	11
12	Arousal Continuum	8	11
13	Neuroendocrine/Hypothalamic	11	11
14	Primary Sensory Integration	7	11
	Limbic		
15	Reward	9	11
16	Affect Regulation/Mood	9	11
17	Attunement/Empathy	6	10
18	Psychosexual	10	10
19	Relational/Attachment	6	10
20	Short-term memory/Learning	6	11
	Cortex		
21	Somato/Motorsensory Integration	5	11
22	Sense Time/Delay Gratification	7	9
23	Communication Expressive/Receptive	5	11
24	Self Awareness/Self Image	9	9
25	Speech/Articulation	5	11
26	Concrete Cognition	6	10
	Frontal Cortex		
27	Non-verbal Cognition	5	9
28	Modulate Reactivity/Impulsivity	5	9
29	Math/Symbolic Cognition	3	9
30	Reading/Verbal	4	9
31	Abstract/Reflective Cognition	3	9
32	Values/Beliefs/Morality	7	9
	Total	232	338

Current CNS Confidence Level: Moderate



Current Relational Health Confidence Level: Moderate

Functional Brain Map(s) and Key

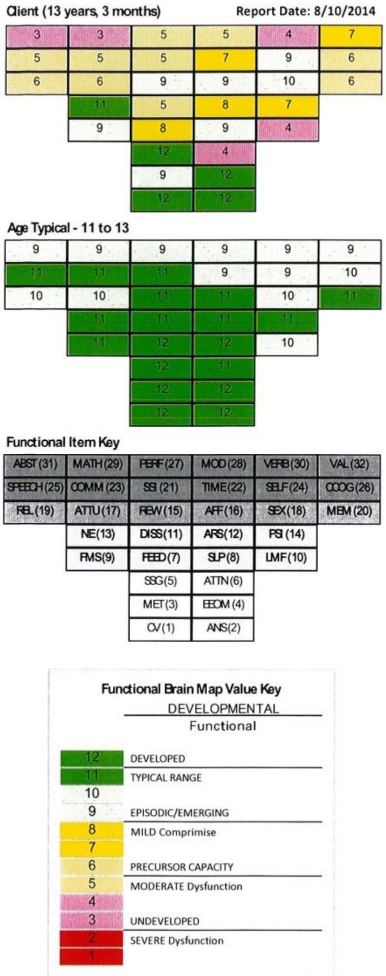
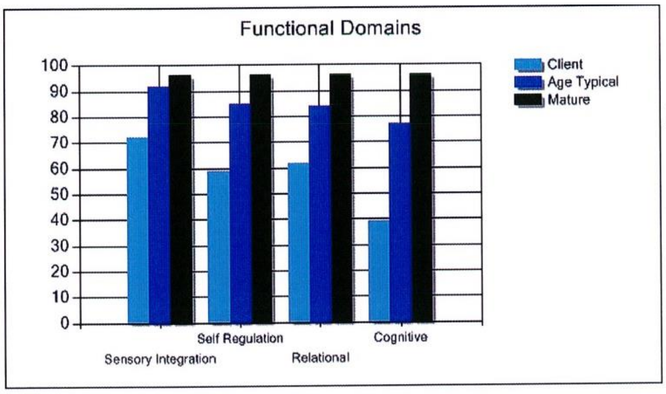


Figure 6.3 Printed with permission from NMT ChildTrauma Academy

Figure 6.4 provides a graph showing Learner B's progress across four key developmental domains, namely sensory integration, self-regulation, relational and cognitive, in comparison to age typical peers. For example, cognitively she is on par with a six to seven year old.

Figure 6. 4 Functional status in comparison to age-typical peers: Learner B



Functional Domains Values

	Client Age	Age Typical	Mature	% Age Typical
Sensory Integration	72	92	96	78.26
Self Regulation	59	85	96	69.41
Relational	62	84	96	73.81
Cognitive	39	77	96	50.65
Cortical Modulation Ratio	1.46	7.00	24.00	20.91

Figure 6.4. *Printed with permission from NMT ChildTrauma Academy*

6.3.1.3 Data from ALSUP (present challenges)

The highlighted areas in Table 6.17 summarises the key challenges for Learner B at present. These correspond with "often" and "very often" categories on the Likert Scale format.

Table 6.17 Present challenges for Learner B as per ALSUP

ALSUP: Lagging Skills
1. Difficulty handling transitions, shifting from one mindset or task to another. 2. Difficulty doing things in a logical sequence or prescribed order. 3. Difficulty persisting on challenging or tedious tasks. 4. Poor sense of time. 5. Difficulty reflecting on multiple thoughts or ideas simultaneously. 6. Difficulty maintaining focus. 7. Difficulty considering the likely outcomes or consequences of actions (impulsive). 8. Difficulty considering a range of solutions to a problem. 9. Difficulty expressing concerns, needs, or thoughts in words. 10. Difficulty understanding what is being said. 11. Difficulty managing emotional response to frustration so as to think rationally. 12. Chronic irritability and/or anxiety significantly impede capacity for problem solving or

ALSUP: Lagging Skills
heighten frustration. 13. Difficulty seeing the "grays"/concrete, literal, black-and-white, thinking. 14. Difficulty deviating from rules, routine. 15. Difficulty handling unpredictability, ambiguity, uncertainty, novelty. 16. Difficulty shifting from original idea, plan, or solution. 17. Difficulty taking into account situational factors that would suggest the need to adjust a plan of action. 18. Inflexible, inaccurate interpretations/cognitive distortions or biases (e.g., "Everyone's out to get me," "Nobody likes me," "You always blame me, "It's not fair," "I'm stupid"). 19. Difficulty attending to or accurately interpreting social cues/poor perception of social nuances. 20. Difficulty starting conversations, entering groups, connecting with people/lacking other basic social skills. 21. Difficulty seeking attention in appropriate ways. 22. Difficulty appreciating how his/her behavior is affecting other people. 23. Difficulty empathizing with others, appreciating another person's perspective or point of view. 24. Difficulty appreciating how s/he is coming across or being perceived by other. 25. Sensory-motor difficulties.
ALSUP: Unresolved problems
1. Shifting from one specific task to another. 2. Getting started on/completing class assignments. (Difficulty entering into tasks) 3. Interactions with a particular classmate/teacher. (Often bullied by peers) 4. Behavior in hallway/at recess/in cafeteria/on school bus/waiting in line. (Does not distinguish between happy excitement and angry excitement which puts her in harms way. Stays in an onsite programme facility during recess for safety reasons). 5. Talking at appropriate times. 6. Academic tasks/demands, e.g., writing assignments. 7. Handling disappointment/losing at a game/not coming in first/not being first in line.

Table 6.17 Printed with permission Lives in the Balance

6.2.1.4 Summary of Learner B's main characteristics

Learner B's vulnerabilities correlate with a general description of what it means to have global development delay. To explain, Baroff and Olley (1999) describe how from a very early age onwards learners with global development delay tend to fall behind in the acquisition of reading, writing, and number skills. They are more prone to displaying behavioural difficulties in class and tend to have shorter concentration-attention spans and lower frustration levels. In addition, they often demonstrate poorer motor skills and coordination compared to typical learners. Moreover, it is common for a learner with this condition to use shorter, simpler sentences and to be less articulated than his/her peers. On balance, a general overall immaturity is described.

Learner B's strength include a love for writing, a willingness to "have a go", and a passion for animals, particularly dogs.

Her last school report indicated that she was working on skip counting in 2s, 5s, and 10s, and that she has to develop a sense of grouping as a pre-cursor to multiplication.

6.3.2 EASTER EGG HUNT

6.3.2.1 Learner B's characteristics

In this section I discuss the characteristics that Learner B displayed during the Easter Egg Hunt cycle:

- **Session 1:** Learner B joined the group and contributed to the discussion. She was the only one of the group who was keen on inviting other classes to be part of the hunt. During the class discussion of the challenge and how it would work, she asked for clarification on the virtual aspect of the hunt.
  - **Asking questions to clarify the problem**

    Learner B*:* *How are they going to find the treasure if it is on the computer?*

- **Session 2:** Initially, Learner B did not volunteer any options with regards to where to hide the treasure, in spite of being invited to do so. She listened to her partner and wanted to copy his writing. I asked her not to copy her partner's work, but to close her eyes and walk around the school in her mind, moving my finger next to my head as I spoke to her. Thereafter she said, "office". I left her a while before asking for more ideas. When she did not respond, I repeated the same strategy, but this time as I positioned my finger next to my head and before I could verbalise the strategy she said "canteen". She produced two more options on her own, "media" and "staffroom", then copied the rest from her partner (garden, library, and small groups). Most of her time during the task was spent writing words down in her book, some of them her own and some taken from her partner. She appeared really tired 10 minutes into the session and closed her eyes, while leaning back into the chair. After the brainstorming session, she drew a map to the treasure, and listened to her partner when I asked him to share his ideas with her. Once her partner left, we spoke a bit more about the treasure that she wanted to buy. She could not work out the mental mathematics that emerged around the idea of buying a treasure prize for $5. To explain, she argued that if she bought hot cross buns for $5, there would still be money left for something else.

- **Session 3:** She interacted with her peers for a while. For example, she laughed at the suggestions of her male peer on hiding the treasure marker in the girls' toilet to prevent the boys from getting to the treasure. She read the list of possible locations brainstormed the previous day to the new group member to give him some options at the start. When the new member asked what the room was called where we were in, she answered "Easter Egg Hunt", which did not make sense in the context of the question.

The rest of the time, she doodled with her pen, stared at the table, watched the other learners write their directions down and listened to them when they spoke. I asked her to listen how the other learners were using directional words and then to apply it to her own choice of location.

.Thereafter, she wrote *walk forwards,* which she changed to *walk out of the class go forwards. S*he did not continue thereafter. After a while, I called her aside and asked her to walk with me through the class, out the door, into the passage, while giving me the directions as she physically walked. I only mediated as far as right outside the classroom door, as I could not leave the rest of the class unattended.

- **Session 4:** She was camping with her family and not at school that day.

6.3.2.2 Learner B's processes

In the next section, I consider Learner B's cognitive functions in relation to Feuerstein's theory and, specifically, cognitive functions from the Elaboration Phase. The cognitive functions I selected for this study from Feuerstein's list, and how these were demonstrated in Learner B's case can be found in Table 6.18.

i) Assessment

Table 6.18 Cognitive functions from the Elaboration Phase: Learner B

Cognitive Function (Independent or Emerging)		**Evidence**
Search for relevant cues	**I**	Could identify the problem and worked with information that was relevant to the problem
Spontaneous need to compare	**E**	Learner B worked with one option. There was no evidence of spontaneous comparisons in her representations
Use of logical evidence	**E**	When asked to provide a reason for her choice, she said "it was because there was lots of space". This was the exact same reason that was given by her partner earlier on and it is likely that she copied it from him

Cognitive Function (Independent or Emerging)		**Evidence**
Abstract thinking	**E**	Drew a basic map Struggled with "mental maths" Teacher: *You think it is about $5. If the hot cross buns are $5 would there be anything left for cookies and cream?* Learner B: *Yes.* Teacher: *How much do you think would be left for the cookies and cream?* Learner B: *[Silence]*
Make a plan - think forward	**E**	She was hesitant to develop her own ideas and more comfortable with "copying" from her partner Teacher: *So, Learner B, what do you think? Where would be a good place?* Learner B: *[Silence]* Learner A: *No, I thought we could hide it in the veggie patch next to the scarecrow.* Teacher: *That sounds like a good plan. Near the scarecrow... Okay write it down.* Learner B: *Shall I write that down too?* Teacher: *Learner B you write down the place you want to choose... Unless you want to go with Learner A's idea?*

Table 6.18

ii) Mediation:

Table 6.19 contains a description of how I mediated Learner B's cognitive functions to help her build a stronger model.

Table 6.19 Mediation: Learner B

Session 1:

Teacher: *So, Learner B, what do you think? Where would be a good place?*

Learner B: *[Silence]*

Teacher: *Try and see the school in your mind. See yourself walking through the school. Which place are you thinking of?*

Learner B: *Office!*

Teacher: *Any more ideas?*

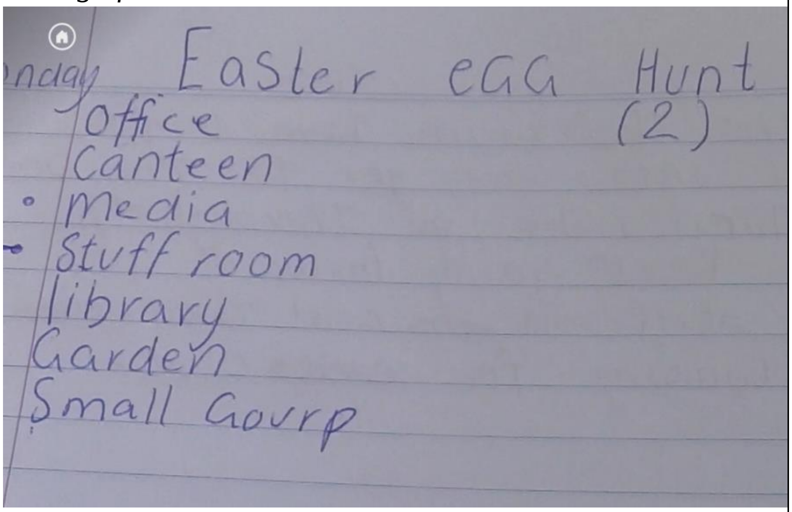
Learner B: *[Silence]*

Teacher: *[positioning finger next to head]*

Learner B: *Canteen*

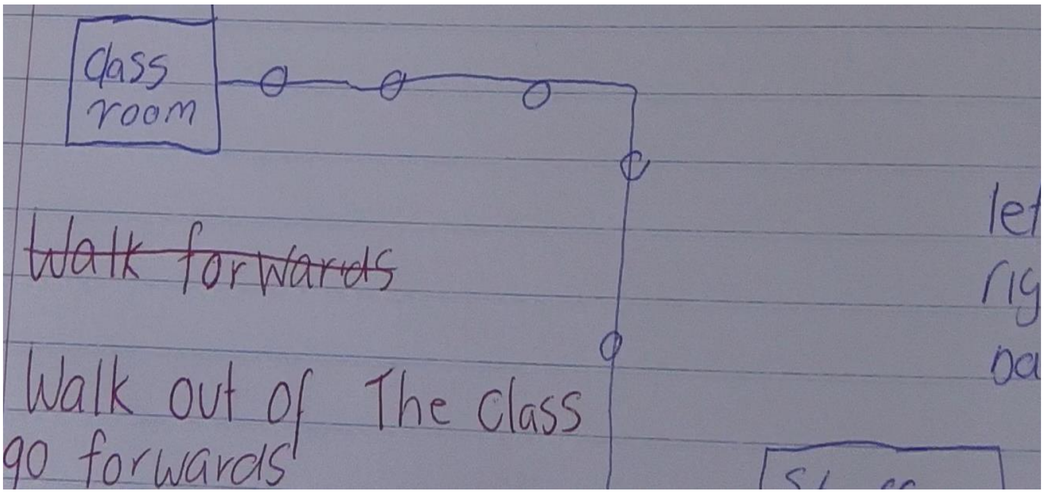
Learner B: *Media... Staffroom*

[copied rest from partner]



Session 2:

Before mediation she produced *walk forwards.* Then changed it to *walk out of the class go forwards.*



The mediation:

Teacher walks with Learner B: *We are going out the class. Do we turn left or right?*

Learner B: *Turn right.*

Teacher: *Then what?*

Learner B: *Walk straight to the door.*

Teacher: *After the door?*

Learner B: *Turn right out of the building.*

Teacher: *That is it Learner B. Do you see what it looks like? Do you think you can now write it down?*

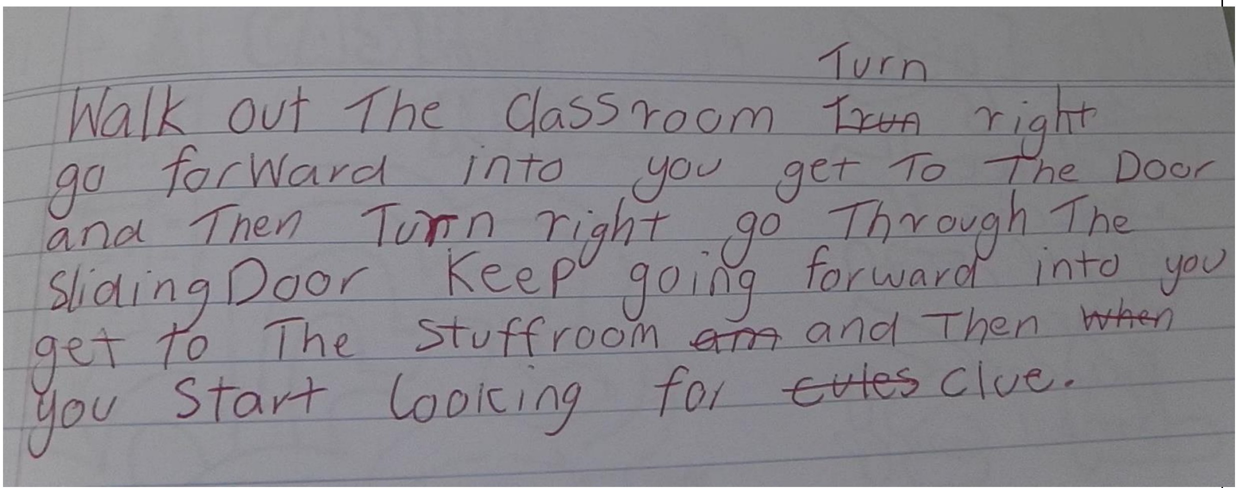

Walk out The Classroom ~~Trun~~ Turn right go forward into you get To The Door and Then Turn right go Through The Sliding Door Keep going forward into you get to The Stuffroom ~~am~~ and Then ~~when~~ you Start looking for ~~cules~~ clue.

Table 6.19

6.3.3 DEFUSE THE BOMB

In this section, I discuss the learning characteristics that Learner B demonstrated during the *Defuse the Bomb Challenge*.

6.3.3.1 Learner B's characteristics

- **Session 1:** Learner B did not look at the bomb while I was explaining its mechanisms. She was playing with the audio recording device, holding it up as microphone. Once the learners started with the activity, she seemed keen to be the scribe, jumped up to get a whiteboard marker and wrote down *Team 1* in big writing. She played with the pen for a long time, doodling away and ignoring her partner and the bomb. When I invited her to have a look at the bomb, she took it from her partner and began to turn the dials, but as I moved towards the table she let go of the device and moved back to the spot with her writing. Since she was not working with her partner, I asked her to move to a spot closer to him on the other side of the table where she could see the device clearly, and asked her partner to work with her by letting her write the numbers down. However, when I moved away from her group she went back to doodling. At this point, her partner became upset with her and started name-calling since he was frustrated that she was not working with him. Following this incident, I swapped groups around and had her join Learner A to work with him as her partner from the next day onwards.

At the end of the mathematics lessons, I became her partner, showing her the relationship between the dial and rotors, checking whether she understood clockwise and anticlockwise turns, directing her to look at and work with the device. I also asked her to walk along in a circle, showing me a ¼ turn, ½ turn and so on as she went.

- **Session 2:** Learner A and Learner B were now partners. I went over to their table and reminded them of the task and of the need to collaborate. I explained that it meant that they had to work together by communicating with one another and by helping one another with the different roles of turning the dial, watching the rotors, counting the turns, and recording the information. Learner B listened to me, while resting her head in the cup of her hand supported by her elbow on the table. She commented "*It is like Pacman*", referring to the rotors lining up at the back. After this, she was involved in the task for the rest of the lesson. She told her partner when to stop, he gave her the number on the dial, and she wrote it down with his help. When she struggled with writing down the fractions, her partner told her how to do it, sometimes rubbing out her work and writing over it. Towards the end she became tired, and leant her head on her arms for a while, but when her partner called out a number, she resumed writing.

- **Session 3:** During the testing phase, learners had to first check their data from the previous day within their groups. To this end, Learner A read out the instructions they compiled together the previous day, while Learner B turned the dial. After this, a member from the other team came to test their set of directions, Learner B read out loud the directions, with help from her partner, while the member from the other team tried to follow it on the dial. She struggled reading fractions, pronouncing ½ (half) as 1 ½ (one and a half). Since the member from the other group was not able to defuse the bomb with their directions, they had to recheck them. Her partner did most of the rechecking while she watched. Again she read out the instruction at the second test by a member of the other team. By the time they had the code, and it was verified by the other team, she was yawning and appeared really tired.

6.3.3.2 Learner B's processes

In Table 6.20, I show how Learner B's cognitive functions were mediated during the *Defuse the Bomb Challenge.*

Table 6.20 Cognitive functions from the Input Phase: Learner B

Cognitive Function (Independent and Emerging)		**Evidence**
Focus and Perceive	**E**	She only looked at the bomb very briefly (3 seconds) before intervention
Systematic Search	**E**	She turned the rotors and dials, and occasionally looked at the back to see if the rotors lined up, but only after the second intervention
Know where you are in space (clockwise, anticlockwise)	**E**	She needed time to think about clockwise and anticlockwise, would hesitate, move in one direction and then self-correct "No, wait…!" and turn the dial in the other direction. In other words, given time she

Cognitive Function (Independent and Emerging)		**Evidence**
		could work it out, but she was not fluent
Be aware of time (how much, how often, sequence)	**E**	She was not counting the turns on the dial, only looking at the number where she stopped
Conserver constancies	**E**	She understood ¼ from as the movement from 0 to 3 on the dial, but not from 5 to 8 per se
Collect precise and accurate data	**E**	She tried to be accurate, but needed help from Learner A at times
Use more than one source of information (turn, direction, distance)	**E**	She could only work with two source of information independently, being whether she turned clockwise or anticlockwise and the number on the dial at that point

Table 6.20

In the section below I explain how I mediated with Learner B:

- **Day 1:**
  - First mediation: I invited her to come over (away from her writing) and to have a look at the bomb, showing her the connection between the rotors and the wire and letting her defuse the bomb. She was able to defuse the bomb by aligning the rotors, but could not give me the code.
  - Second mediation: I encouraged her and her partner to work with one another, showing them in a step-by-step manner how they could work together to record the data. For example, I explained that one of them had to watch the back to see if the rotors lined up, and that one of them needed to keep track of the front. When the back lined up, the one partner had to say stop, and record in conjunction with the other partner the number on the dial and the number and the directions of the turn.

- Third mediation: For the last few minutes of the maths lesson, I became her partner. I took her aside and we assumed different roles. In one session, she started defusing the bomb, and I played the role of the scribe, and in the next session I started defusing the bomb while she became the scribe. We did not work out the combination code, but basically practiced the different roles and how they worked together. I also checked her understanding of concepts, whether she knew clockwise and anticlockwise, and if she understood the meaning of ¼ turn and ½ turn.

- **Day 2:**

  At the outset of the lesson, I reminded Learner B and her partner of the mechanism of the bomb, and that they had to produce a code together. I suggested that they decide on roles, with one person turning the dials and the other recording the information.

  The graph in Figure 6.5 shows that over time the teacher mediation became less, and Learner B's involvement in the task without mediation increased. Whereas she was not able to work with her partner before mediation, she was able to do so afterwards. Moreover, unlike the day before, she responded to her partner's efforts to include her in the task, thereby allowing him to act as a peer mediator for her. The point I am making is that the way it was used in this mediation was not by solving the "whole problem" with the learners as in direct teaching, but by helping learners focus on key aspects that would help them work with information to solve the problem by themselves. At the same time, the different personalities of the partners were likely also a contributing factor to her willingness to engage in the task.

Figure 6. 5 Mediation decreasing over time

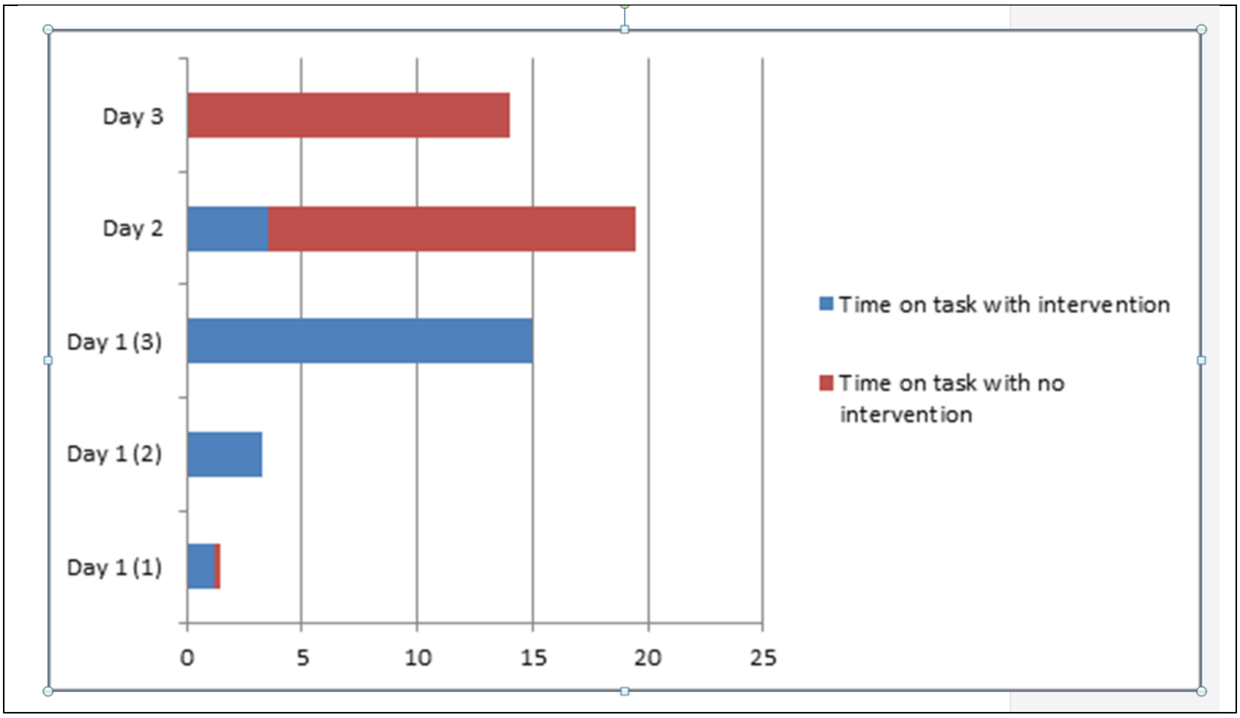


Figure 6.5

6.3.4 FLY THE HELICOPTER

6.3.4.1 Learner B's characteristics

In this section I discuss the characteristics that Learner B displayed during the *Fly the Helicopter Challenge.*

- **Session 1: Building top view with blocks**
  Learner B wanted to build the school structure that contained her classroom and not any other part of the school and its buildings. She worked parallel, and had difficulty interacting with the demands that her peers where making on her, in terms of changing her structure to be in proportion to theirs. She resisted their feedback and ideas. For this reason, her peers became frustrated with her, and eventually Learner A leant over and removed part of her blocks to reduce the proportion of her building. She felt victimised and started crying.

    - **Dealing with feedback**

Learner A: *Somebody needs to make the walkway.*

Learner B: *What, that there?*

Learner A: *That's like a little too big. [Glancing over at Learner B's work]*

Learner B: *I am making that part there.*

Learner A: *That is too big.*

Learner B: *That is small.*

Peer: *Maybe just cut it in half. Look like there [shows with his hands]*

Learner B: *Have that bit there. It is too big. [Points to another area]*

Learner B: *It is small there [pointing to the screen], but it is big outside.*

Learner A: *We are making a small structure of it.*

Peers: *Yeah! Yeah!*

Learner B: *We are not making a huge structure.*

Learner A: *[Leans over and removes blocks from her structure to make it smaller] That's perfect!*

Learner B: *[upset] No! Stop telling me what to do. You're bossy, saying do this, do that.*

Peer: *Dumb, dumb, dumb! [Singing softly]*

Learner B: *[Starts crying softly]*

- **Session 2: Drawing (3D)**
    - Learner B watched the video and laughed at some of the observations that her peers were making of the shape in the media clip, for example, "It looks like the university". She then tried on her own. The first drawing that she showed me was a series of disconnected lines. I asked her to have another "good" look at

shape, after which she produced the second drawing in which some of the lines were connected to form a shape.

- **Session 3: Top view**
    - She watched the tutorial while swivelling in a chair. While I unlocked the iPads, she played with the data projector, blocking the light and making shadows on the wall. When two of her peers asked her to stop, she took little notice of their request, and continued blocking the light while giggling and laughing at the shadows she was creating.
    - After she was handed her iPad, she browsed the Internet, then opened her drawing app, swivelled on the chair, and began playing Minecraft. My response was a general reminder to the class that they will forfeit their choice time later in the day if their work was not done by then. After the reminder, she went out of Minecraft and asked, "So we have to draw the school?". I emphasised that we wanted a top view of the school, and when she did not respond, I asked Learner A to replay the short clip on top view.
    - She watched the video and went back into Minecraft, until I addressed her more firmly about our class agreement on how iPads should be used during lessons. In response she said, "So, Miss I have to draw an L" (referring to the shape on screen from the tutorial). Again, she did not start the task, but swivelled in her chair, looking around. It was only when she saw a peer's completed work and heard him talk me through his drawing, that she made an attempt herself. She sat on the swing chair while drawing. As she talked me through her drawing, she self-corrected it by adding one more building.

- **Session 4: Minecraft**

She was quite chatty in the beginning, talking about her experiences at the show, and mentioning to the group that she was making a chest, but thereafter she drifted out of the conversation, seemingly focused on constructing her chest.

- **Session 5: Choosing one drawing to be a top view**
    - Learner B stated that she chose a picture that looked the same as the school. Learner A, however, disagreed with her and explained that he felt only some areas corresponded to the *Google Earth* model of the school.
- **Discussing options:**

Learner B: *It looks the same.*

Learner A: *Now look at this one here. It is not really the same. Some areas look the same as the picture. Some areas like THAT, THAT, THAT and THAT. Some areas look the same as the picture. That is a good reason.*

Learner B: *What else.*

- **Session 6: Measuring**

  Learner B needed help from Learner A to measure. She was unsure where to start with the ruler. Moreover, she did not write her measurements on the drawing next to the line that she was measuring, but wrote them on the table, separate from the line and the drawing itself. This confused Learner A as he then had difficulty in transferring the information onto the "group copy" that would be used to scale out the school on the oval. Furthermore, Learner A pulled her back into the measuring whenever she lost concentration. Moreover, she really wanted to measure the building that had her classroom inside and she was disappointed when it was taken by another learner.

- **Session 7 and 8: Scaling**

During the group discussion, for a few minutes, she lay down on her arms with her head down as if asleep. She then sat up and swivelled around in the chair, left her partner and the table and moved to the rocking chair. I called her back from the rocking chair to the table. She looked around the room, but not at the paper. Even after saying to her, "look at these blocks", and pushing my finger along the paper to show her, she only glanced at the sheet and then looked away. When the balloon flew past her, she began playing with it. Afterwards, she sat down on the swivelling chair again, swivelling and staring down, and later playing with the ream of tape while still on the swivelling chair.

On the oval, she walked next to her partner and counted out the metres. To lay the tape down, she began unwinding it. Soon the wind caught it and the tape began flapping in the wind. She then tried to roll it back onto the roll. After a few rolls, she gave up, became still and watched the wind blow the tape around. She stood there watching for several minutes. Her partner called her but she took no notice of him. Eventually, I asked Learner B to join her partner. As she moved towards her partner, her tape got caught up with another group's tape. At that point, Learner C started wrapping her up in tape, and she joined the game, running and chasing others and being chased and wrapped. Learner B was the learner who requested that we repeat the activity for her birthday.

Scaling in the classroom: She was active in her group under the delegation of Learner A. Every now and then she would get tired and go and sit out along the side, but Learner A would call her back and give her a choice of which line she wanted to "measure next". He also helped her focus on the wheel while she was measuring. At one point, while Learner A was talking to the LSA, she started drawing hearts on the carpet.

- **Session 9: Designing the grid reference and flying the helicopter**

Learner B did not know how to design a grid reference. Learner A used his grid reference and explained to her how it worked and how to create coordinates, and how to work with these coordinates. Learner B had fun trying to learn how to fly the helicopter.

6.3.4.2 Learner B's processes and representations

i) Assessment

Table 6.21 shows that, for the most part, all of Learner B's cognitive functions were still emerging in the area of Output. An exception was her perseverance, in that she was always willing to come back and have another go.

Table 6.21 Mediation becoming less over time: Learner B

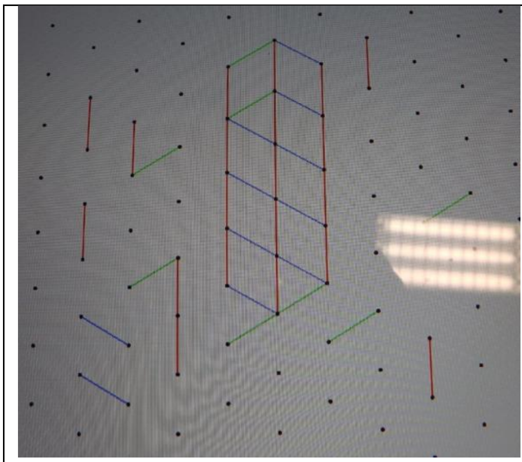
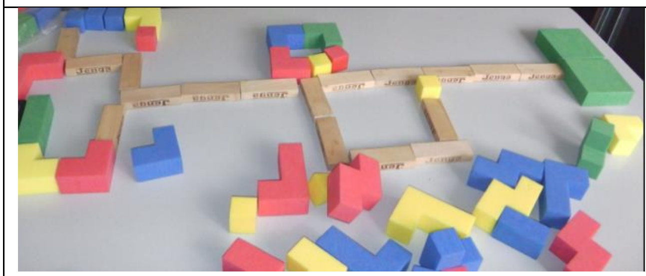
Cognitive Functions (Independent or Emergent)		Evidence
Considering another person's point of view	**E**	She had difficulty accepting another's point of view, e.g. during the block session, she would not adjust her structure on the group's request
Visual transporting (copying accurately from the board or other source)	**E**	Her copies were not very accurate
Perseverance	**I**	She persisted with all the tasks
Avoiding a trial and error response	**E**	She pushed the wheel, initially not paying much attention to the measurements. Learner A walked besides her and helped her focus
Communicating clearly with the right vocabulary	**E**	She had real difficulty expressing herself when she had to provide reasons for her choice of drawing
Use precision and accuracy	**E**	Her worked lacked precision and accuracy
Show self-control	**I**	She was to a large extent able to regulate her own behaviour. She was upset during the block building task, but that is understandable taken that she felt hurt by the group's actions in taking her blocks away

Table 6.21

ii) Mediation

In Table 6.22, I include some of Learner B's representations from the last mathematical challenge, showing evidence of her visual transporting and precision and accuracy skills.

Table 6.22 Learner B's representations from Fly the Helicopter Challenge

	3D view. This was the learner's second attempt. Her first attempt had no connecting lines. The original drawing consisted of a series of separate and disconnected lines as can be seen around the outskirts of this drawing. Intervention: I asked her to go back and have another look at the drawing on the tutorial.
	Her model shows that she is building "from memory" rather than from the data source. The buildings that are present are the ones that she frequents, whereas those more unfamiliar to her are not represented in her model. Moreover, the time it takes to walk down the exterior corridor appears long, as is reflected in her drawing, but in actuality the corridor is proportionately not that long. Intervention: I asked her to explain her model to me and she pointed out the various buildings by name.
	The correct version.

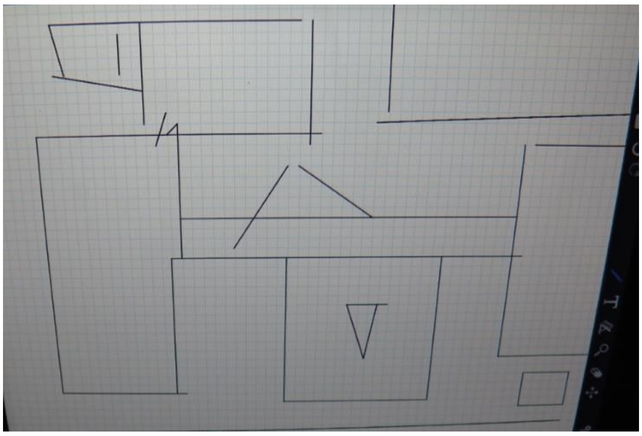
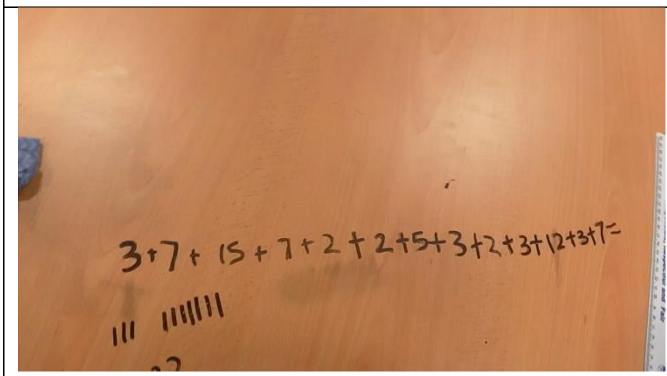
	Mediation: She required mediation to get into the task. Once she showed me her completed drawing, I asked her to talk me through it. She then self-corrected by adding another building. On final analysis, the places she frequents are represented, but the buildings that she does not go to are absent in her drawing. Again, the proportions of her buildings reflect the personal meaning she assigns to them, rather than their actual size. To explain, buildings where she spends a lot of time are unusually large in comparison to other buildings.
	Learner A: *I don't get what she is doing. [Writing measurements on the table and not on the sheet.]* Teacher: *That is why you need to be talking to her. Not me, you need to be talking to her.* Learner A: *You have got to write the number that is on the line. You have got to write the number on the line that is there. It will be easier for me to know what it is!*

Table 6.22

6.3.5 RESEARCH QUESTIONS: LEARNER B

6.3.5.1 What is the relation (if any) between the learning behaviours during mathematical modelling and the psycho-educational profile?

Her strengths were her ability to have a go and her resilience at bouncing back into tasks, even when she felt misunderstood by her peers. On the other hand, her language skills made it difficult for her to express herself, for example, when she needed to justify any decisions or to give an explanation. Moreover, she needed help with focusing, for example, looking at the bomb, and likewise, getting into a task. Her drawings reflect poor visual transport, which is likely related to her visual processing difficulties.

6.3.5.2 How did her cognitive functions influence her modelling?

A large proportion of Learner B's cognitive functions were emergent. This made it very difficult for her to model on her own. She needed mediation to help her enter into tasks, focus on variables, and refine her original model by elaborating on it. Initially, this was provided by me as the teacher, but during the last cycle of modelling, Learner A began to assume some level of mediation as he interacted with her.

6.3.5.3 What evidence of learning can be found in the analysis of learner's reasoning and representations over time?

For the most part, Learner B's models strongly reflected personalised knowledge and memories. As was noted earlier, she needed considerable attention to enter into a task and to stay focused. Moreover, she was able to produce more elaborate models through mediation and through joint activity than on her own. For this reason, her case is a good example of how dynamic assessment proves beneficial as a way of evaluating the progress of learners with SEN. With dynamic assessment, we are able to establish a more positive outlook of her learning advances in modelling. Put differently, should we only evaluate her through more standardised grids such as Galbraith and Clatworthy (1990), it would be easy to miss the progress that she has made in modelling through joint activity, and consequently, the benefits of modelling with regard to her learning of mathematics.

Considering the level of support needed by Learner B during modelling, and the mathematics reflected in her own models, I place her as constructing models with a Level 1 knowledge depth (see Table 6.23).

Table 6.23 Depth of Knowledge: Learner B

Level 1	**Level 2**	**Level 3**	Level 4
Recall a mathematical fact, term, principle or concept Perform a routine procedure or basic computation Locate details	Use mathematical information. Have conceptual knowledge Select appropriate procedures Perform two or more steps with decision points along the way Solve routine problems Organise and display	Develop a plan or sequence of steps Make decisions Justify decisions Solve problems that are abstract, complex and non-routine More than one possible solution Support solutions and judgements with evidence	An investigation or application to the real world Non-routine problems Solve over extended time Requires multiple sources of information

Table 6.23

Student B's progress on a standard modelling matrix is at Standard 1 as show in Table 6.24.

Table 6.24 Progress on modelling matrix: Student B

Criteria	**Standard 1**	**Standard 2**	**Standard 3**
Ability to specify problem clearly	Is able to proceed only when clues are given	Can extract clues from information and translate them into a clear expression of the problem to be solved	Is able to perform as for S2 and in addition can clarify a problem when information is open

			ended insufficient and redundant
Ability to formulate an appropriate model: choose variables and find relationships	Is able to proceed only when clues are provided	Is able to determine important factors and develop relationships with a minimum of assistance	Is able to determine important factors and develop relationships independently where no clues exist
Ability to solve the mathematical problem including, the mathematical solution, interpretation, validation, evaluation/refinement	Is able to solve the mathematical problem given substantial assistance through clues and hints	Is able to solve the basic problem with little or no assistance. Generally unable to refine the model.	Is able to solve the basic problem independently. Is able to evaluate and refine the model.
Ability to communicate results in a written and oral form	Is able to communicate reasonably in regard to layout (including use of visuals), presentation, conciseness, and orally with some prompting	Is able to communicate clearly with good use of aids and without prompting	Is able to communicate clearly with outstanding presentation including innovative creative features

Table 6.24

sTable 6.25 contains comments from Learner B's on her mathematical learning experiences during modelling.

Table 6.25 Reflections on modelling: Learner B

Easter Egg Hunt	Teacher: *What did you learn?* Learner B: *I learnt which way to turn to go places.*

	Teacher:	*How can we change the activities so that you can learn better?*
	Learner B:	*Next time we have to have more chocolates.*
Defuse the Bomb Challenge	Learner B:	*I was trying to get the wire into the thing.*
	Teacher:	*Did you learn anything from it?*
	Learner B:	*I was concentrating. I learnt moving the dial.*
Fly the Helicopter	Learner B:	*Maths is a bit hard.*

Table 6.25

6.4 CASE STUDY: LEARNER C

6.4.1 Psycho-educational profile of Learner C

6.4.1.1 Data from school files (chronologically)

Learner C is a 12 year old male who has an ongoing history of concerns regarding his attention and challenging behaviours, and his consequent ability to stay on-task in classroom situations. He was diagnosed with Foetal Alcohol Syndrome when he was 5 years old by a paediatrician, and more recently with predominantly inattentive type of Attention Deficit Hyperactivity Disorder and Oppositional Defiance Conduct disorder. The support and intervention he has received up to this point in his schooling is documented in Table 6.26.

Table 6.26 Support and intervention history of Learner C

	Event	Assessment	Results of Assessment	Support
Age 3	Removed from his mother Placed with his grandmother, before being moved to foster care	Occupational Therapy	Problem solving was borderline. Fine motor coordination average Personal social skills average Real difficulties with attention, turn taking and task completion	Scheduled visits to family
		Medical officer at the clinic	Ongoing issues with eating behaviour and nutrition (eats small amounts, doesn't recognise when he is hungry)	
Age 5		Paediatrician	Foetal Alcohol Syndrome, failure to thrive	
Age 7		Speech pathology assessment	Moderate difficulties with receptive language, severe difficulties with expressive language	
		Cognitive assessment Naglieri Nonverbal Ability Test. The Stanford-Binet Intelligence Scale: Fifth Edition.	No significant difference between his verbal IQ and non-verbal IQ scores Current level of cognitive ability was in the low average/average range Working memory was borderline impaired or delayed Struggled with change (transition) Challenges in relation to concentration, task completion, keeping track of his belongings, and being organised	Support materially visually and nonverbally Provide routine

	Event	Assessment	Results of Assessment	Support
Age 11	Issues with behaviour, including a attention span of no longer than 30 seconds, scribbling and destroying work when frustrated, overreacting to typical classroom situations such as someone accidently knocking him, being paranoid about people talking "about him" when they are not, constantly tapping and signing, absconding from home and school, and self-harming.	Paediatric outpatient clinic Vanderbilt questionnaires by his carer and primary school teacher	Confirmed clinical features of foetal alcohol syndrome (microcephaly, smooth philtrum, short palpebral fissures). New diagnosis of predominantly inattentive type of ADHD Oppositional defiance conduct disorder	School arrange one-on-one support in the classroom environment Ritalin
Age 7 - 12	Primary school years Popular with peers			Joined small group run by a special education coordinator once a week. Cognitive strategy work: - memory skills, processing speed and verbal comprehension One-to-one speech support focusing on receptive and expressive language and grammar High levels of distractibility

Table 6.26

6.4.1.2 Data from brain map (function and structure of brain)

As shown in Figure 6.6, Learner C has ongoing difficulties with attention (brain stem area), with sleeping at night (cerebellum), with regulating his own behaviours and emotional state, with language (cortex), and with doing academic work in general (frontal cortex). His strengths are that he has well-co-ordinated large muscle movement which makes him fairly agile and good at sports. He is also sociable, seeking out conversations with others.

Figure 6. 6 Functional brain map: Learner C

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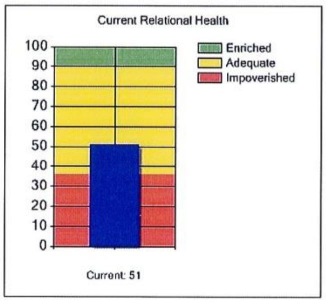
Current CNS Functionality

		Client	Typical
	Brainstem		
1	Cardiovascular/ANS	12	12
2	Autonomic Regulation	12	12
3	Temperature regulation/Metabolism	8	12
4	Extraocular Eye Movements	6	12
5	Suck/Swallow/Gag	12	12
6	Attention/Tracking	3	11
	DE/Cerebellum		
7	Feeding/Appetite	7	12
8	Sleep	5	12
9	Fine Motor Skills	10	11
10	Coordination/Large Motor Functioning	10	10
11	Dissociative Continuum	7	11
12	Arousal Continuum	3	11
13	Neuroendocrine/Hypothalamic	10	11
14	Primary Sensory Integration	11	11
	Limbic		
15	Reward	8	11
16	Affect Regulation/Mood	7	11
17	Attunement/Empathy	7	10
18	Psychosexual	9	10
19	Relational/Attachment	7	10
20	Short-term memory/Learning	11	11
	Cortex		
21	Somato/Motorsensory Integration	11	11
22	Sense Time/Delay Gratification	5	9
23	Communication Expressive/Receptive	6	11
24	Self Awareness/Self Image	3	9
25	Speech/Articulation	9	11
26	Concrete Cognition	7	10
	Frontal Cortex		
27	Non-verbal Cognition	4	9
28	Modulate Reactivity/Impulsivity	6	9
29	Math/Symbolic Cognition	3	9
30	Reading/Verbal	4	9
31	Abstract/Reflective Cognition	3	9
32	Values/Beliefs/Morality	4	9
	Total	230	338

Current CNS Confidence Level: Moderate



Current Relational Health Confidence Level: Moderate

Functional Brain Map(s) and Key

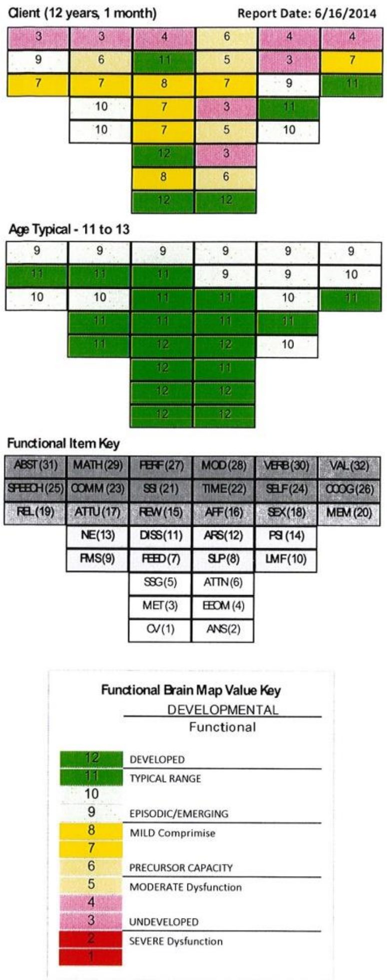
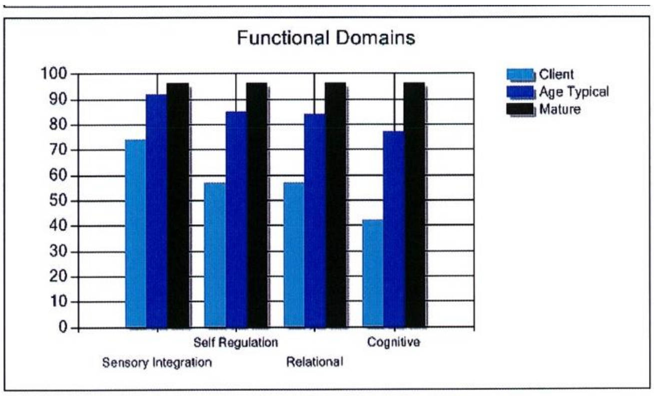


Figure 6.6

The graph in Figure 6.7 shows Learner C's progress across four key developmental domain, namely sensory integration, self-regulation, relational and cognitive, in relation to age-typical peers. For example, cognitively Learner C is functioning at half his age, meaning he is on par with a 6- to 7-year-old in this regard.

Figure 6. 7 Functional status in comparison to age-typical peers: Learner C



Functional Domains Values

	Client Age	Age Typical	Mature	% Age Typical
Sensory Integration	74	92	96	80.43
Self Regulation	57	85	96	67.06
Relational	57	84	96	67.86
Cognitive	42	77	96	54.55
Cortical Modulation Ratio	1.43	7.00	24.00	20.50

6.7 *Printed with permission from ChildTrauma Academy*

6.4.1.3 Data from ALSUP (present challenges)

The highlighted areas in Table 6.27 summarise the key challenges for Learner C at present. These correspond with "often" and "very often" categories on the Likert Scale format.

Table 6.27 Present challenges for Learner C as per ALSUP

ALSUP: Lagging Skills
1. Difficulty handling transitions, shifting from one mindset or task to another. 2. Difficulty doing things in a logical sequence or prescribed order. 3. Difficulty persisting on challenging or tedious tasks. 4. Poor sense of time. 5. Difficulty reflecting on multiple thoughts or ideas simultaneously. 6. Difficulty maintaining focus. 7. Difficulty considering the likely outcomes or consequences of actions (impulsive). 8. Difficulty considering a range of solutions to a problem. 9. Difficulty expressing concerns, needs, or thoughts in words.

10. Difficulty understanding what is being said. 11. Difficulty managing emotional response to frustration so as to think rationally. 12. Chronic irritability and/or anxiety significantly impede capacity for problem solving or heighten frustration. 13. Difficulty seeing the "grays"/concrete, literal, black-and-white, thinking. 14. Difficulty deviating from rules, routine. 15. Difficulty handling unpredictability, ambiguity, uncertainty, novelty. 16. Difficulty shifting from original idea, plan, or solution. 17. Difficulty taking into account situational factors that would suggest the need to adjust a plan of action. 18. Inflexible, inaccurate interpretations/cognitive distortions or biases (e.g., "Everyone's out to get me," "Nobody likes me," "You always blame me, "It's not fair," "I'm stupid"). 19. Difficulty attending to or accurately interpreting social cues/poor perception of social nuances. 20. Difficulty starting conversations, entering groups, connecting with people/lacking other basic social skills. 21. Difficulty seeking attention in appropriate ways. 22. Difficulty appreciating how his/her behavior is affecting other people. 23. Difficulty empathizing with others, appreciating another person's perspective or point of view. 24. Difficulty appreciating how s/he is coming across or being perceived by other. 25. Sensory-motor difficulties.
ALSUP: Unresolved problems
1. Shifting from one specific task to another. (Difficulty transitioning from class to class on his timetable) 2. Getting started on/completing class assignments. (Struggles to remain focused.) 3. Interactions with a particular classmate/teacher. (Teasing of certain peers). 4. Behavior in hallway/at recess/in cafeteria/on school bus/waiting in line. (Destroys property during break times. Stays in protected garden area during recess) 5. Talking at appropriate times. 6. Academic tasks/demands, e.g., writing assignments. (At times, very reluctant to write). 7. Handling disappointment/losing at a game/not coming in first/not being first in line.

Table *6.27 Printed with permission Lives in the Balance*

6.4.1.4 Summary of Learner C's main characteristics

For the most part, Learner C's characteristics are congruent with a description of the typical profile of learners with foetal alcohol syndrome disorder

(FASD). FASD has a very strong effect in the cognitive domain including overall intellectual functioning, attention/working memory, executive skills, speed of processing, inhibitory control and academic skills (McCreight, 1997, p. 7-30; Nuñez, Roussotte & Sowell, 2011, p. 121, Warren, Hewitt & Thomas, 2011, p. 4-14).

His primary strength is his social nature and strong co-ordination. Consequently, he seeks out interactions with others and he enjoys sport.

His latest primary mathematical report before moving to middle school indicated that he had an incomplete knowledge and understanding of the Year 6 content and a very limited competence in using skills and following processes. It was noted that he needed explicitly structured lessons, constant reassurance and encouragement, and support. His report further indicated he had made minimal progress in his year level, that he did not attend to tasks quickly or independently, and that he needed teacher direction to start. It was also observed that he was still developing his group work skills. He was working on strategies to calm himself down. It was noted that he had a negative attitude towards mathematics, resulting in unfinished work, which was compounded by his poor recall of basic number facts. It was also recorded that he fared better in practical tasks and discussion than in recording information.

6.4.2 EASTER EGG HUNT

6.4.2.1 Learner C's characteristics

In this section I discuss the learning characteristics that Learner C demonstrated during the *Easter Egg Hunt Challenge*.

- **Session 1:** Learner C was reluctant to join the group. He eventually came, and brought his iPad along after refusing to let go of it on request. He listened to me, but was very distracted by the iPad. He rubbed his eyes frequently, tugged at the iPad, and every now and then made eye contact with me, while trying to open his iPad in the hope that I would not notice. He contributed to the group discussion by making suggestions and participated in the voting sessions.

- **Participating in a group discussion**

  Teacher: *Who wants to divide our class into groups or who wants to a have competition with another class?*

  Learner C: *What about two and two? [Pointing to others] People like them too and them too. Two by two – so it is them two and us two. So it is like us two and them both.*

- **Session 2**: Learner C engaged in some singing and giggling with a peer. He then settled down trying to find Adelaide, and in particular the Beach House, where he just came from holiday the day before. Throughout the session he maintained a parallel type of running commentary with a peer, letting each other know where they were in *Google Earth*. In spite of reminders that the treasure had to be in the local town, he remained intent on finding Adelaide.

  - **Locating Adelaide**

    Learner C: *Yeah. mmm. Adelaide. I am going to hide my treasure in Adelaide. Where is this beach house?*

    Peer: *I am going to hide it in China.*

    Learner C: *I am going to hide mine in Africa.*

    Peer: *China!*

    Learner C: *You don't know what China is like.*

    Peer: *China!*

Learner C: *Wait, I am nearly there. No, where the hell am I?*

Peer: *I am just going to put it in the middle of the ocean.*

Teacher: *Remember, it must be in our town.*

- **Session 3:** Learner C came into the room, sat down at the table and wrote swear words on the table with a whiteboard marker. I asked him to assume the responsibility for moving through *Google Earth* with the mouse, and thereafter he got caught up in the activity. He knew his way around town, but was slow to use directional language.

6.4.2.2 Learner C's processes and representations

i) Assessment

The cognitive functions I selected for this study from Feuerstein's list, and how these were demonstrated in Learner C are found in Table 6.28.

Table 6.28 Cognitive functions from the Elaboration Phase: Learner C

Cognitive Function (Independent or Emerging)		**Evidence**
Search for relevant cues	**I**	He could identify the problem, but did not work with information that was relevant to the problem (worked with Adelaide as his destination instead of working with his own town)

Cognitive Function (Independent or Emerging)		Evidence
Spontaneous need to compare	**E**	He did not compare any options. Only focused on Adelaide, even when prompted to consider other options Teacher: *Peer has a suggestion. The shopping centre.* Learner C: *I found it. I found the airport. Look I found the racing track.* Teacher: *What do you think? Is that good spot? [referring to the peer's suggestion]* Learner C: *[no response]*
Use of logical evidence	**E**	When his peer asked him what he was doing in Adelaide, he did not provide any justification. Learner C: *Where is Adelaide, I forgot.* Learner C: *Found it!* Peer: *Adelaide? What are you there for?* Learner C: *Found Adelaide!! Where is the beach house again?* Learner C: *Wait! Wait! Where is it again?*
Abstract thinking	**I**	He was able to describe his way around town by "visualising it". Peer: *No, listen to me because Miss is confusing herself. Hey, Learner C you and me are right. Hey. You turn left to go to the shopping centre, hey.* Learner C: *Yes, you turn left to go to thing... You turn left to go to the shopping centre and then you go straight across and then you go round the roundabout and then you turn.*
Make a plan - think forward	**E**	He would not set up the treasure hunt with the others, and his behaviour was disruptive during this time. He pushed Learner A off the chair when he felt that Learner A was not following the directions correctly.

Table 6.28

i) Mediation

- **First mediation attempt:**

He also did not respond to general clues to the group to choose a local location for their treasure.

- **Second mediation attempt:**
  During the second session, his response was mediated by a peer in the group.

Learner C:	[Learner C turns the wrong way on *Google Earth*]
Peer:	*NO! The other way. Other way. The other way.*
Learner C.	*The bus goes this way.*
Peer:	*Yes, but through here you go that way*.

6.4.3 DEFUSE THE BOMB

In this section I discuss the learning characteristics that Learner C demonstrated during the *Defuse the Bomb Challenge*.

6.4.3.1 Learner C's characteristics

- **Session 1:** Learner C was not present at the start of the lesson as he was in a behaviour management session. Consequently, he arrived late, near the end of the session. He was slightly agitated and paced around the room, but kept going back to his peer who was trying to defuse the bomb, standing silently next to his peer, watching him work the dials. At one stage, when his friend let go of the dial to have a rest, he took the device and began turning the dials, trying to work it out. When his friend took the device back, Learner C paced the room again, but after a while went back to watch his friend.

- **Session 2**: The next day, he joined a partner and the LSA explained the problem to him alongside others who came in late from camping. He gently blocked the LSA's hands as she pointed out the parts of the device to the learners, and drew the bomb to him, touching it and turning the dial. At first he would turn the dial, then look at the back, then look at the back, and turn the dial. Five minutes into the session, he changed the angle of the device so that he could see the dial and the rotors at the same time. His group was sitting near the door, and when a learner from another class came and stood swinging in the doorway, Learner C took no notice him and continued. He was reminded that he needed to work with his partner, and that he needed to tell his partner the numbers on the dial and the information with respect to the turns. His partner was the scribe. They worked well together, with Learner C saying the numbers on the dial and telling her about the turns he made, while she wrote it down.

- **Session 3**: The next day he joined another group as his partner was away camping. I asked him to be scribe for a while to allow another learner time with the device. He knew clockwise and anticlockwise. He knew ¼ and ½ turn if it matched basic drawings. But he did not recognise it if it was irregular, say from 5 on the dial to 8, turning clockwise. He couldn't represent 2 ½, for example (drawing or otherwise). He started losing focus after getting the fractions wrong, but still tried by telling his partner to stop and by writing it down. However, after 5 minutes he got up, walked around the classroom, then found another bomb and sat by himself for another 6 minutes trying to work it out, very intent. Thereafter his friend finished in his group and started playing with the camera, and Learner C got up and joined in.

6.4.3.2 Learner C's processes and representations

Table 6.29 shows which of Learner C's cognitive functions were strong and which ones were still emerging and provides evidence for these evaluations.

Table 6.29 Cognitive functions from the Input Phase: Learner C

Cognitive Functions **(Independent or Emerging)**		**Evidence**
Focus and Perceive	**I**	He looked intently at the dials and the rotors and how they affected one another
Systematic Search	**E**	At one point he became more systematic in that he turned the angle of the dial, so that he could see both the rotors and the dial at the same time
Know where you are in space (clockwise, anticlockwise)	**I**	He knew clockwise and anticlockwise
Be aware of time (how much, how often, sequence)	**E**	He knew that the rotors had to line up at the back, and could count the number of turns in whole numbers, not in fractions
Conserve constancies	**E**	Understood ¼ as the movement from 0 to 3 on the dial, but not from 11 to 2 per se
Collect precise and accurate data	**E**	He made an attempt to be accurate and precise, but his range of data collection was very limited and he would not record the data (write it down)
Use more than one source of information (turn, direction, distance)	**E**	He could work with two sources of information at a time, the direction of the turn (clockwise or anticlockwise) and the number on the dial

Table 6.29

i) Mediation

In Table 6.30, I show how Learner C's cognitive functions were mediated during the *Defuse the Bomb Challenge.*

Table 6.30 Examples of Learner C's representations from Defuse the Bomb Challenge

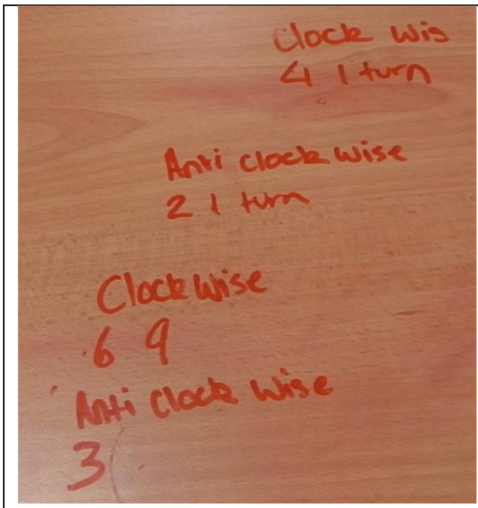
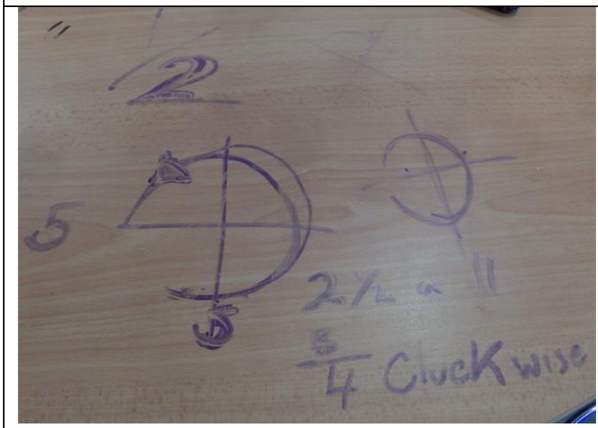
 	During his first session with the bomb, Learner C turned the dial and reported the information, which was captured by his partner who played the role of the scribe. Noticeably, he did not incorporate fractions into his work.
	Learner C's first attempt at showing clockwise or anticlockwise in writing.
 	During Learner C's second session, I mediated as follows with the intent of helping him collect recorded data: Teacher: *Are you ready? Let's start. You tell me if she is going clockwise or anticlockwise. Remember to tell her where to stop.* Learner C: *STOP!* Teacher: *What number was that?* Peer: *5* Teacher: *Clockwise or anticlockwise?* Learner C: *Anticlockwise* Teacher: *Let's write that down so we can remember it.* Teacher: *How many turns did she make?* Learner C: *Boom!*

Table 6.30

6.4.4 FLY THE HELICOPTER

In this section, I discuss the characteristics that Learner C displayed during *Fly the Helicopter Challenge.*

6.4.4.1 Learner C's characteristics

- **Session 1: Building Blocks**
  Learner C ignored his partner altogether in terms of task discussion. He looked at the computer screen, took the blocks and started building. Unlike the other teams, who constructed the blocks across the length of the table, he used the width of the table. He worked and thoughtfully matched his work to the screen as he went along. His partner started joking with him, about two-thirds of the way through his construction. He immediately lost interest in the task, and started joking back, followed by dancing and singing in front of the camera. I returned to the room, and asked him to finish his project with his partner. He walked to the other side of the table, quickly put his blocks together and did not refer back to the computer screen again after that.

- **Session 2 and 3: Drawing (3D and top view)**
  Learner C was the member of the class who left before the start of the video, being angry and upset after recess, and then came back later during the video and settled on a bean bag to watch the short tutorial. He did not attempt a 3D drawing that day, but stayed quietly on the bean bag biting the tips of his fingers. However, he did attempt the top view drawing during the next session. Again, he sat on the bean bag while completing his drawing of top view on the iPad and thereafter talked me through his buildings.
- **Session 4: Minecraft**

The Minecraft activity brought out considerably more strengths in Learner C than the other activities. To illustrate, he gave corrective feedback to peers on their work, praised himself for his efforts, and showed a strong sense of ownership.

Learner C: *Peer come here. I can do it.*

Peer: *No I can.*

Learner C: *No, you can't. You are not doing it right. I am doing it right. Like this. I am doing it all right. That one is over there. I just did this. I just did this. This is a genius move.*

Learner A: *Ah! Nice!!*

Learner C: *No-one touches mine.*

Learner C: *Miss, that one is mine. That is the one I just made. That one is mine. I am making this one for Learner A.*

- **Session 5: Choosing a drawing from all the drawings**
  Learner C had difficulty moving away from the Minecraft objects into the next activity. I had gathered up the Minecraft objects and left them on a side table the day before. During this session, learners were asked to move to the round tables in the middle of the room and join their groups. Learner C would not leave the Minecraft objects. He positioned himself on his knees next to the table and continued to touch and play with the objects. When I called him over to the groups, he briefly came, looked at the drawings, very quickly chose one without giving a reason, and then went back to the table with the Minecraft objects.

- **Session 6: Measurement**
  Learner C was part of the group who had problems settling and started off by playing games, until the LSA went to sit at their table. Yet, after the other two members settled, Learner C did not. He tried to reengage with the group by joking with them, but at that stage the group members kept going on with their work. At this point he went over to the corner of the

room where he hit furniture with the ruler, creating a loud and very distracting banging sound. After he was advised to stop, he settled next to fish and started building his own fishing line with the rulers. He spent the rest of the lesson trying to catch the fish.

- **Session 7 and 8: Scaling**

  During the group discussion, he stayed on the couch, away from the group. He did not join any group or get involved in the discussion, yet he appeared to be listening to the conversation. As soon as the visitor's balloon drifted his way, he began playing with it, moving around the room bouncing the balloon. I called him to join the groups, but he disregarded the request and continued tapping the balloon into the air. The class left very shortly after that for the oval.

  On our arrival, Learner C began playing with his measuring wheel, trying to push it on the oval, but his wheel kept getting stuck. It took him a while to get his measuring wheel working. He then measured out the first line, walking next to another group who was counting out and keeping up with them. He ran back to fetch the security tape, but never went back to his group. Instead, he started wrapping up his peers in the security tape, thereby starting the game which ended the maths lesson.

  Scaling in the classroom: Learner C wanted to continue with his game from the previous day, and started wrapping learners up in security tape once again. The learners objected, and I asked him to leave the game behind and to continue with the lesson. He found an object lying around and was using it as a spear in the LSA's face. She became upset when he would not stop and reprimanded him. After that he left, and would not return to the group. Likewise, he refused to go with the group to the physical exercise class straight after maths. I took this opportunity to work with him one-on-one, with me reading out the measurements and him rolling the wheel and chalking the lines. He seemed content working one-on-one.

- **Session 9: Designing the grid and flying the helicopter**
  The next day, since he did not want to join in with the groups, I partnered with him and we designed a grid reference together, while sitting on the rocking chair. He seemed to know how to design a grid and got it done fairly quickly. Thereafter, he joined the group to fly the helicopter. In contrast to the measuring and scaling task, he was completely involved in working with the others in figuring out how to fly the helicopter. In addition, he was trying hard to work out how to help a peer who had difficulty getting the helicopter off the ground. To this end he experimented with several options, including using a block as a helipad pad, throwing the helicopter into the air at take-off to give it more life, and changing the materials of his helipad to see which ones would create more support.

6.4.4.2 Learner C's cognitive processes and representations

In Table 6.31, I describe Learner C's cognitive functions of the output phase. Aside from a tendency for precision and accuracy, the rest are still emerging.

Table 6.31 Cognitive functions from the Output Phase: Learner C

Cognitive Functions (Independent or Emerging)		**Evidence**
Considering another person's point of view	**E**	He did not seem to reflect on how his own actions were disrupting the learning of others
Visual transporting (copying accurately from the board or other source)	**I**	Learner C's foam block structure and drawing of top view is fairly accurate, which reflects independent visual transporting skills
Perseverance	**E**	He could persevere with some tasks such as Minecraft, drawing and flying the helicopter, but he could not persevere with tasks such as measuring and scaling

Cognitive Functions (Independent or Emerging)		**Evidence**
Communicating clearly with right vocabulary	**E**	Learner C had difficulty expressing himself using appropriate maths vocabulary or communicating a reasoned response, as opposed to a conversational response which he could do fairly well
Just a moment, let me think (avoiding trial and error responses)	**E**	Learner C continued to show much impulsive behaviour throughout this activity. Another example includes his quick evaluation of the drawings. It was an immediate intuitive choice Learner C: *Can you put them a bit closer. That one.*
Use precision and accuracy	**I**	Learner C was very precise in his Minecraft objects, and helped others who were "not doing it right", according to him
Show self-control. (Don't panic or fret when you don't know).	**E**	Learner C had real difficulty controlling his impulses and resorted to disruptive behaviours, for example, banging on the furniture or trying to distract his peers in other ways.

Table 6.31

In Table 6.32, I include some of Learner C's representations from the last mathematical challenge, showing evidence of his visual transporting and precision and accuracy skills.

Table 6.32 Examples of Learner C's representations

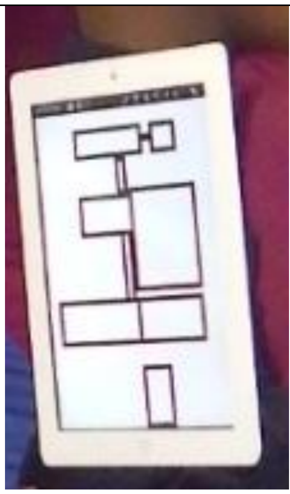
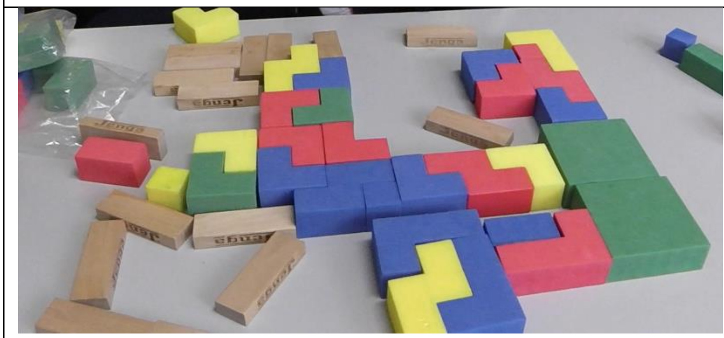
Correct version.	 Learner C's drawing of top view. His showed drawing accuracy and reasonably strong visual transport skills.
	Learner C's attempt at constructing a top view of the school.

Table 6.32

6.4.5 RESEARCH QUESTIONS: LEARNER C

6.4.5.1 What is the relation (if any) between the learning behaviours during mathematical modelling and the psycho-educational profile?

I chose Learner C as an example of an outlier. When compared to the other learners in the class, he had the most difficulty in adjusting to the tasks, specifically in terms of his behaviour and participation. Yet, as I analysed the videos, I was surprised at how much he was actually involved in the activities. Accordingly, I drew up a list of activities in which he was an active participant, and compared it to a list where he would not get involved. This list is found in Table 6.33. At the end of the table I conclude that he was willing to engage and able to regulate himself relatively independently during activities that were more sensory in nature, as opposed to activities that related to writing and recording data.

Table 6.33 Comparing modelling tasks that Learner C participated in and those he did not

Active Participant - could sustain engagement	**Refused to participate - could not sustain engagement**
Giving verbal directions in *Google Earth*	Recording the directions
The actual treasure hunt, running around, reading the clues and looking for the treasure	Setting up the hunt (writing out the directions)
Defusing the bomb by lining up the rotors	Recording the combination
Minecraft	
Building with blocks (at start)	
Watching video on 3D blocks	
Drawing top view of the school	
Choosing between different options	Debating the choice
Pushing the measuring wheel, while a partner measured	Doing the measurements, working out the scale
Designing a grid reference (drawing)	
Sensory (visual, tactile, kinetic)	**Writing**

Table 6.33

Thereafter I compared these findings to his brain map, which shows that he has significant delays in certain of the lower levels of the brain. In such instances, Perry and Hammond (2008) recommend that educational interventions should start from the bottom upwards, thereby addressing the lower regions of the brain first. Moreover, in their work the lower levels of the brain are related to somatosensory activities. This could explain why Learner C participated in and benefitted from modelling activities that work with the senses, such as running after treasure, turning a dial, and building a Minecraft chest. Additionally, Learner C's upper brain or cortical regions are very vulnerable, which could explain why activities like measuring, recording data, and debating positions were difficult for him. Vygotsky reminds us that we cannot push too far ahead in the ZPD, but that we need to adjust to the learner's developing level (not developed level) and pull along from there.

6.4.5.2 How did his cognitive functions influence his modelling?

All things considered, Learner C received fairly limited mediation, both from myself as the teacher and from his peers in general. During the *Easter Egg Hunt Challenge* he was in conversations with peers, which I did not interrupt. He did not, however, respond to clues given in general to the group. During the setup of the Easter Egg Hunt, I was too busy helping the others to give him one-on-one mediation, aside from having a brief conversation with him with regards to his behaviour. Likewise, during the second session of the bomb, a peer worked with him, and during the third session I spent time with him trying to mediate his recording of data. By the third challenge, the plan in the research was to step back and see how the learners would do without direct mediation, that is, whether peers would step into this role. This was the case with Learner A helping Learner B. Yet, noticeably no-one in the class tried to mediate Learner C's challenges. The reasons for this are open to speculation and will need to be researched further. However, when I worked with him towards the end of the session, for example, when the rest of the class went to physical exercise, he was willing to map out a scale with me on a one-to-one basis, and the next day he designed a grid reference with me as his partner.

The point being made here is that modelling in its pure form, groups working together, may not be helpful in Learner C's case, seeing that the group for the most part made little attempt to help him settle down. In Learner C's situation, direct mediation with an adult may prove more beneficial until he develops additional skills. On the other hand, he was able to join in the groups with certain tasks, as is shown in Table 6.37. Therefore, it may equally well be a matter of design and mediation working together to create the kind of mathematical learning experiences Learner C would need.

6.4.5.3 What evidence of learning can be found in the analysis of learner's reasoning and representations over time?

On balance, I assessed Learner C as using a Level 1 depth of knowledge in his models (see Table 6.38) and, according to mainstream criteria, I would place him at a Standard 1 level in terms of his modelling capability from a mainstream perspective (see Table 6.35).

Table 6.34 Depth of Knowledge: Learner C

Level 1	**Level 2**	**Level 3**	Level 4
Recall a mathematical fact, term, principle or concept Perform a routine procedure or basic computation Locate details	Use mathematical information. Have conceptual knowledge Select appropriate procedures Perform two or more steps with decision points along the way Solve routine problems Organise and display	Develop a plan or sequence of steps Make decisions Justify decisions Solve problems that are abstract, complex and non-routine More than one possible solution Support solutions and judgements with evidence	An investigation or application to the real world Non-routine problems Solve over extended time Requires multiple sources of information

Table 6.34

Table 6.35 Progress on modelling matrix

Criteria	Standard 1	Standard 2	Standard 3
Ability to specify problem clearly	Is able to proceed only when clues are given	Can extract clues from information and translate them into a clear expression of the problem to be solved	Is able to perform as for S2 and in addition can clarify a problem when information is open ended insufficient and redundant
Ability to formulate an appropriate model: choose variables and find relationships	Is able to proceed only when clues are provided	Is able to determine important factors and develop relationships with a minimum of assistance	Is able to determine important factors and develop relationships independently where no clues exist
Ability to solve the mathematical problem including, the mathematical solution, interpretation, validation, evaluation/refinement	Is able to solve the mathematical problem given substantial assistance through clues and hints	Is able to solve the basic problem with little or no assistance. Generally unable to refine the model.	Is able to solve the basic problem independently. Is able to evaluate and refine the model.
Ability to communicate results in a written and oral form	Is able to communicate reasonably in regard to layout (including use of visuals), presentation, conciseness, and orally with some prompting	Is able to communicate clearly with good use of aids and without prompting	Is able to communicate clearly with outstanding presentation including innovative creative features

Table 6.35

Last, Table 6.36 contains reflection from Learner C on his modelling learning experiences.

Table 6.36 Reflections on modelling: Learner C

Easter Egg Hunt	Teacher: *What did you learn from this activity?* Learner C: *I did not learn anything!* Teacher: *You did not learn anything?* Learner C: *I did not get to do anything.* Teacher: *We saw video clips of you helping everyone work out the directions.* Learner C: *Wait! I wanted the airport!*
Fly the Helicopter	Learner C: *I hate mathematics. It's boring!*

Table 6.36

6.5 A SUMMARY OF RESEARCH QUESTIONS FROM Task F (IMPLEMENTATION)

Task F had three research questions attached to it, which were analysed at the end of each case study. Below I provide a brief summary of the results.

6.5.1 What is the relation (if any) between the learning behaviours during mathematical modelling and the psycho-educational profile?

There is clear evidence to suggest that the characteristics of learner's psycho-educational profiles impact on their modelling. Modelling made different demands on learners, depending on their strengths and their vulnerabilities.

6.5.2 How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?

I have shown how, from the position of building mathematical models of real situations, educators need to collaborate with the learner in the challenge to help the learners stretch beyond their current modelling capacity. The educator collaboratively supports the learner's unfolding experience and takes the lead when there are indications that certain cognitive functions need to be strengthened.

6.5.3 What evidence of learning can be found in the analysis of learner's reasoning and representations over time.

Throughout the study, I have introduced some of the challenges around defining evidence of learning in a SEN environment. Additionally, operationalizing evidence in a problem-solving environment is not straightforward either. Granted that, I argue that there is enough evidence in this study to support that learners with SEN learn mathematics from modelling, even when learning is defined from within several different paradigms. For example, from a behaviourist perspective, learners had opportunity to practice skills (measuring), there were moments of explicit teaching, particularly in relation to social norms, and even opportunities to participate in more drill- and practice-like routines (turning a dial clockwise or anticlockwise over three days). From a Piagetian constructivist perspective, representations from the learners indicated that they experienced several incidences of cognitive disequilibrium, which they then actively sought to resolve. Moreover, the activities allowed for some "hands-on" learning, and it gave learners opportunity to connect several concepts (shape, measurement, direction, scaling) instead of working with concepts in isolation. Likewise, from Social Constructivist perspectives there was evidence in the learners' representations of attempts to talk mathematics together by asking questions and communicating ideas, and by assuming different roles such as peer tutoring and mentoring. From a situated cognitive perspective, their representations showed knowledge applications in real-life situations by giving directions around town, for example. And, from a distributed cognition perspective, learners worked with technology in an appropriate manner both in terms of looking for solutions and to represent their ideas. Last, from a modelling perspective, the representations of learners produced evidence of models being refined over time with mediation.

6.6 RESEARCH QUESTION FROM TASK G: REFLECTION

Task G: Reflection

Conduct an audit to generate data on how the design is evolving and its actualization of general learning principles:

- How does the learners' learning correspond with the proposed learning trajectory?
- To what extent does modelling benefit and/or impede the mathematical learning of learners with SEN: an evaluation against Tyler's (2013) general learning principles.

6.6.1. How does the learners' learning correspond with the proposed learning trajectory?

The *Easter Egg Hunt Challenge* and the *Defuse the Bomb Challenge* followed the hypothetical learning trajectory. However, changes had to be made to the HLT during the *Fly the Helicopter Challenge*. The first change was in respect to introducing the Minecraft activity. As explained previously, I introduced the Minecraft templates as a filler activity to allow time for learners to prepare their work for the intended activity of choosing the best rendering of top view. Consequently, learners had a chance to print their work and remove their names, while the LSA enlarged their drawings to A3 size on the school's colour photocopier. Moreover, learners became so caught up in the Minecraft activity that it became a lesson in itself.

The next couple of changes were all related to creating a scaled model of the school. As explained before, a scaled model was necessary as the remote-controlled toy helicopter had a shorter than expected battery life, which meant that it could not fly to the actual school buildings, as originally planned. Moreover, I anticipated that scaling would be a small diversion, yet in the end the scaling took up a substantial amount of lesson time. This was influenced by a number of factors. First, the learners did not work out a scale, but immediately started measuring all the lines of the top view drawing, which took up a session. Then, learners had real difficulty with the concept of transferring information from their individual drawings to a single drawing. Last, the windy day made scaling on the oval difficult, and produced the need to create a scaled model indoors. For the most part, the learners' work showed that they had significant difficulties with measuring, which was noted in my reflection. On the positive side, learners had a chance to practice measuring, and the more capable learners showed their peers how to use a ruler. However, to sum up, the learning experiences around measuring were unintended in the original HLT.

6.6.2 To what extent does modelling benefit and/or impede the mathematical learning of learners with SEN?

I answer this question by evaluating the term "benefit" against Tyler's (2013) principles of general learning experiences. Tyler (2013, p. 971) evaluates learning experiences from the perspective of the learners responded to the experiences. These principles are listed in Table 6.37

Table 6.37 Tyler's (2013) principles of general learning experiences

Principle 1 (a): Learners must have experiences that give them opportunities to practice the kind of behaviour implied by the objective. That is to say, if the objective is to develop skill in problem solving, then the learners must be given ample opportunity to solve problems.	Achieved
Principle 1 (b): The learning experiences must give learners opportunity to deal with the kind of content implied by the objective.	Achieved
Principle 2: Learning experiences must be such that the learner obtains satisfaction from carrying on the kind of behaviour implied by the objectives.	Mostly achieved

Principle 3: The reactions desired in the experience are within the range of possibility for the learners involved.	Partly achieved
Principle 4: There are many particular experiences that can be used to attain the same educational objectives.	Achieved
Principle 5: The same learning experience will usually bring about several outcomes.	Achieved

Table 6.37

6.6.2.1 Principle 1 (a): Learners must have experiences that give them opportunities to practice the kind of behaviour implied by the objective. That is to say, if the objective is to develop skill in problem solving, then the learners must be given ample opportunity to solve problems.

Learners were given opportunities to problem-solve challenging problems over four weeks. For the most part, all learners were actively involved in the activities. Put differently, they "had a go". The exception was Learner C, who experienced more difficulty than the other learners with settling into a group and becoming an active participant. Yet, as was pointed out, there were many activities that he was actively engaged in, with the common element being that these activities were somatosensory in nature.

6.6.2.2 Principle 1 (b): The learning experiences must give learners opportunity to deal with the kind of content implied by the objective.

The problem-solving was based on mathematical concepts from ACARA, with a specific focus on *Location and Transformation,* which translates into giving and following directions from an everyday perspective (left and right), from a turning perspective (clockwise, and anticlockwise), and from a grid reference perspective (using coordinates). A subsidiary focus was on shapes where learners constructed 2D and 3D shapes as treasure markers, created 3D shapes from nets, drew 3D shapes, built structures with 3D shapes, and explored top view. In addition, the construction of a scaled drawing of the school introduced measurement and scaling.

6.6.2.3 **Principle 2:** Learning experiences must be such that the learner obtains satisfaction from carrying on the kind of behaviour implied by the objectives.

Overall, the learners were positive about the Easter Egg Hunt, the Defuse the Bomb Challenge, and the Top View activities, but less so with regard to the measuring and scaling activity.

To illustrate, after the Easter Egg Hunt event, four learners approached me to ask if they could have another treasure hunt soon. Likewise, during the learner interviews, learners showed enthusiasm in their response to the bomb challenge. Themes such as "You got me working" and "I was concentrating" emerged during the learner interviews.

During the Minecraft activity, learners called me over and requested that I buy more of the nets so that they could create a "Minecraft village".

Teacher: *Ok! Tell me about your idea.*

Learner 1 *: We are thinking of building a whole house. Maybe a whole like thing*

Learner 2: *Yeah! We need to get like these. And then we can find like these. But…*

Learner 3*: The whole thing.*

6.6.2.4 **Principle 3:** The reactions desired in the experience are within the range of possibility for the learners involved.

The range in the learners' mathematical understanding was significantly large. Learner B and Learner C worked at Year 0/1/2 level in their personalised programmes during class, while Learner A was working on a Year 8 level. Still other learners were on a Year 3/4 level. For the most part, differentiation for an individual is more straightforward than differentiation for a group setting, in particular where the range of mathematical understanding is the difference between entry into primary school and exit of primary school (a large chunk of the primary school years are largely missing in some learners, whereas others are coping with high school concepts). To accommodate the range of difference in mathematical concepts, I worked with the design principle of flexibility and access, meaning creating an instructional task where all learners would have some level of access, in other words, be able to start, but would not necessarily end up at the same learning point by the end of the activity. To illustrate, in the bomb challenge Learner B was consolidating her understanding of clockwise and anticlockwise, Learner C was working on the meaning of fractions (how many turns are 1 ½ turns on a dial) and combining two levels of information, the number of the dial and the number of turns, and Learner A was learning to combine multiple sources of information. In the end, only Learner A successfully solved the problem. In other words, Learner A arrived at the intended ideal outcome, whereas his peers were still developing aspects of mathematics and were functioning at stages on the way towards the end goal. Yet, all the learners were involved in the activity and expressed during the learner interviews that they had learnt something from it.

6.6.2.5 **Principle 4:** There are many particular experiences that can be used to attain the same educational objectives.

i) Assigning groups

The first experience related to how we should group learners and promote positive group work experiences to attain their educational objectives. Since learners were largely functioning in parallel, it became important to consider how to introduce group work processes to them.

Several options were trialled:

- No grouping structure is pre-assigned. Grouping is left open, such as in the Minecraft tasks, learners decide whether they want to work in a group or not. Most learners sat in proximity to one another, but preferred to work alone.
- The learners choose the task. The task decides the group structure, for example, as in the Easter Egg Hunt. Those learners who wanted to plan a virtual treasure hunt were in one group and those who wanted a local treasure hunt were in another.
- Teacher assigns groups based on ability. This was undermined by personality clashes. The stronger learners were more competitive, which created conflict. Also, more mathematically capable and less mathematically capable groups in some instances engaged in name-calling as learners picked up on the power differences.

- Teacher assigns groups based on safety. This is the type of grouping that won out in the end. Putting learners with others who treated them well, no-naming calling, bullying, and so on.

ii) Redefining collaboration

My own working definition at the beginning of the study was as follows: "learners *have to work in small groups* in a collaborative manner and create solutions by combining their implicit knowledge drives with discussion and reflection". In my own mind, modelling was about problem-solving, which took place in the context of a small group throughout the various phases, from beginning to end. Yet, during the research it became apparent that learners may need some time alone with the task, to think about the problem on their own, before starting the group sessions. Consequently, in the *Fly the Helicopter Challenge*, I began to explore design options that would give learners time to first do the task individually before engaging in a group solution. For example, learners created their own top view drawing before collaboratively deciding which one to use for the scaling. The process allowed them to first formulate an individual solution, thereafter to clarify and justify their perspective on which drawings would be most suitable, and then to engage in a joint decision-making process by making a final decision. Consequently, it allows for a gradual building up towards working with others and understanding their perspectives within a modelling cycle.

Consequently, I am revising my conception of modelling to incorporate designs that will allow for a range of options — individual time, partnership time, small group time, whole group time — merging together in a supportive and balanced learning sequence.

iii) Drill and practice

Modelling is often contrasted to drill and practice. However, the bomb design was a good example of how these two processes do not necessarily have to exist separately. To explain, over the three days of defusing the bomb, learners had to repeatedly turn the dials clockwise and anticlockwise while indicating that they were doing so to their partners, or to themselves, in order to produce the code for defusing the bomb. There was no complaints of the activity becoming tedious. On the contrary, learners used their non-contact time and own choice to sit with the device to try to work out the code.

iv) Connecting mathematical concepts

As per the local school's collaborative planning schedule, the SEN unit intended to cover number patterning, money, and time in the first term; location for the first five weeks, and shape for the last five weeks of the second term; likewise, measurement and data collection in the third term, and so on. In contrast to this type of insular planning approach to mathematical concepts, the study demonstrated how modelling draws on a range of concepts and connects them in meaningful ways. Shape and measurement became an integral and natural part of location, as did other aspects of mathematics, such as mental mathematics and proportionality. Making connections is important to learners with SEN as it extends learning beyond knowing skills to activating and developing understanding (Harpaz, 2007).

6.6.2.6 **Principle 5:** The same learning experience will usually bring about several outcomes.

i) Knowledge types: social processes or mathematical knowledge?

On several occasions during the study, I came across the tension of which knowledge type development to favour In particular, whether I lean towards developing social and communication skills in the hope that learners will benefit more from one another's mathematical ideas and contributions, or whether I favour individual mathematical acquisition? An example in the study related to Learner C during the *Easter Egg Hunt*, where I interrupted his dialogue with a peer to include another learner as the scribe. Likewise, I interrupted Learner A's problem-solving at the beginning stages of the *Defuse the Bomb Challenge* by insisting that he takes turns with his partner in handling the device. To resolve this conflict, I applied the following rule of thumb. Where I thought learners would be able to "bounce back" into their thinking, I interrupted them, but where learners were more hesitant in terms of developing their ideas, I gave them extended time before asking them to pay attention to the social dynamics. For example, Learner C and his peer were involved in a conversation and, even though I interrupted them numerous times to remind them to include the shy scribe, they were able to go straight back into their conversation. Similarly, Learner A's desire to solve the problem was strong enough for him to resume his inquiry after his partner had a turn.

ii) EAP goals

Modelling provides a natural platform for accommodating and working towards the EAP goals of learners with SEN. To clarify, in this study Learners A and C had the goals of developing more appropriate social interactions, and Learner B had the goal of improving concentration. The progress that the learners made during modelling in terms of their goals were demonstrated in the case study analysis. For example, Learner B self-reflected that the bomb challenge helped her concentrate, whereas Learner A reported on being more aware of the advantages of group work.

iii) Outcomes pertaining to life

In the next section, I elaborate more on this topic, giving examples of how outcomes aside from "direction" developed and were attained. These include language development, understanding when and how to use technology, and practical aspects such as not measuring around furniture but to go mentally "through" it, or how to give directions when encountering a roundabout on the road. To this end, Vygotsky (1926/1997) reminds us of the importance of having instructional activities that empower learners with SEN to function in and contribute to the real world.

> Ultimately, only life educates, and the deeper that life, the real world, burrows into the school, the more dynamic and the more robust will be the educational process. That the school has been locked away and walled in as if by a tall fence from life itself has been its greatest failing. Education is just as meaningless outside the real world as is a fire without oxygen, or as is breathing in a vacuum. (p. 345)

One aspect that is worth mentioning is the element of belonging, camaraderie and being "comfortable" with others. To illustrate, several of the learners who participated in the study, for safety reasons, have a predetermined place for them to go during recess and lunch. For example, Learner A typically goes to the library, Learner C to a small garden area, and Learner B visits an onsite programme facility. The week following on from the research, the library was closed for marking purposes, and the onsite programmes closed due to a field trip. During this time, the vulnerable learners from class grouped together around an outside table and acted as support and protection for one another. In addition, a few vulnerable learners from other classes came and joined them as well. I was made aware of this when a colleague discussed with me how worried she was over the facilities being closed for the week, and how relieved she was to see the learners together in a group supporting one another. Even though it is speculation as to how much modelling contributed to this, I find it significant that similar scenarios did not happen in the term before the modelling took place, only afterwards.

6.6.3 Additional frameworks of programme evaluation

As was noted earlier, I chose Tyler's framework to guide the primary evaluation, for the reason that Tyler claims that his approach is learner-centred, in that it evaluates curricular designs from the learners' perspectives and experiences. However, the programme can also be evaluated from a theoretical stance and from the perspective of practice, such as the teacher's role as described in modelling literature.

For example, the programme can be evaluated against an established modelling framework such as RME. Treffers (1987) states that RME has five characteristics, namely, the use of contexts, the use of models, the use of learners' own productions and constructions, the interactive character of the teaching process, and the intertwinement of various learning strands. Likewise, the challenges in this study were situated in real or imagined situations where learners had to construct their own models, while being mediated by the teacher or fellow peers, and had to use various strands of the curriculum concurrently to create solutions.

From a practice perspective, I described in the chapter on modelling (see Section 3.4) the role the teacher is expected to play. In Table 6.38, I evaluate the modelling tasks against these criteria.

Table 6.38 Evaluating the design against principles from theory

Principle from modelling	**Outcome in this study**
The teacher has to select suitable problems, where suitable means problems which can be problematized (mathematized), that are realistic and that are rich	As a designer I feel confident that the designs met these criteria in that they stimulated mathematical thinking, linked to other knowledge systems, such as life-application and fantasy, and that the learners self-reported on finding certain of the tasks challenging and motivating.
The teacher needs to let the learners experience cognitive conflict	I discussed several examples of cognitive conflict experienced by the learners elsewhere, yet there are others that can be added. Teacher: *These look very complicated. I think… very nice [looking at some of the Minecraft objects]* Learner: *They are not complicated… they are very hard. See, I just figured it out now… It took all this time.* Teacher: *What did you figure out?* Learner: *This. I figured out how to build this.[holding up a character from Minecraft]*
The teacher has to mediate between learners and between learners and content	I illustrated throughout the case studies how I mediated using Feuerstein's list of cognitive functions as my guideline.
Teacher has to help learners formalise their knowledge	Developing mathematical language and mathematical tools such as basic maps and grid reference systems are all strategies towards helping learners formalise their knowledge.

Principle from modelling	Outcome in this study
Teachers have to help learners generalise	The focus of this study was on providing support for the learners through mediation. It did not explicitly measure learners' ability to transfer or generalise to other situations. However, when opportunities to evaluate transfer spontaneously occurred in other teaching opportunities throughout the day, I recorded it. For example, I previously mentioned that during the English lesson a peer was trying to find Nepal on the globe, and Learner C was directing him saying "Go there, no there" while pointing with his finger and trying to take the globe control out of the peer's hand. I asked Learner C to "use his directional language" instead. He was able to change language focus quite easily, using phrases such as "move right, a little more, too much, left again". Another situation related to the collaborative aspect of modelling, and not to mathematical knowledge as the example above, and emerged when the social worker came to do an activity with the class. Social Worker: *Now for this activity, I need you to work as a team.* Learner A: *Oh, I know! Like the bomb!* These scenarios suggest that elements of transfer are taking place, but further research is needed to validate these early observations.

Principle from modelling	Outcome in this study
Teachers have to believe that learners learn through modelling	Throughout this study I promoted Vygotsky's view that we should not wait until we feel that learners are ready for modelling, but that we should use modelling as a ZPD for developing learners so that they can become ready for modelling. Moreover, I tried to illustrate how using dynamic assessment captures a more positive outlook on learners being able to benefit from modelling in terms of their learning, than measuring movement along a standardised grid.

Table 6.38

6.7 RESEARCH QUESTION FROM TASK H OF THE DESIGN

6.7.1 How viable is modelling as an instructional approach in a SEN classroom

In this section I consider how viable modelling is as an instructional approach in a SEN classroom based on an analysis of learning characteristics, processes and representations in mathematical modelling of middle school learners with special needs? I argue that modelling is viable if it can contribute to practice and to theory.

6.7.2 Contribution to practice

Modelling contributes to practice in three ways:

- it is suitable as a tool for inclusive practice
- it is suitable as an environment for cognitive education
- it is suitable as an environment for life education

6.7.2.1 Tool for inclusive practice

Considering how independent many of Learner A's cognitive functions were, we consulted with Learner A, his family, and the mainstream teachers, for him to trial mainstream. The mainstream mathematics teacher mentioned that he did quite a bit of group work in his class, and made the decision to let Learner A join a small group, which consisted of girls only, during collaborative learning activities. Since then Learner A has also joined mainstream classes with Design and Programming and English. Weekly monitoring, which includes follow-up discussions with his teachers from mainstream, and with Learner A himself, indicated good progress in his mainstream environment, in spite of two incidents of victimisation by male peers in the mainstream class. His placement into mainstream may not have been likely if I only looked at his onDemand scores (standardised testing) which placed him at a Year 3–4 level of mathematics. The point I am making is to reiterate the value of dynamic assessment types as a gauge to the learning potential of learners with SEN and, consequently, their suitability to mainstream environments.

6.7.2.2 A suitable environment for cognitive education

My own position is that modelling is an ideal model of a "thinking curriculum" with its emphasis on learning as an intellectual and interpretive enterprise in conjunction with others, and in respect to its contextualised and challenging realism approach. Vygotsky believed that the main purpose of education was to cultivate psychological processes that will enable higher-order reasoning and thinking skills. This is in contrast to standard education where the purpose of schooling is to provide content that learners manage with their already existing psychological tools (Kozulin, 2014, p. 567). Alongside Vygotsky, I argue that the main curricular goal of learners with SEN should be the development of their higher-order reasoning processes. To this end, I believe modelling offers a natural fit to the concept of a cognitive curriculum. I also maintain that modelling steadfastly results in increasing adaptive thinking, and the learners' abilities to manage open-ended problems are directly related to its embedded function as a suitable cognitive curriculum.

To illustrate the power of modelling as a cognitive curriculum, I suggest we compare what happened during these modelling activities to Kozulin's (2014) description of the features of a Vygotskian cognitive curriculum:

> Students are taught to consider the goals, methods, and means of their actions. To do this, they are introduced to the notion of the mental schema of the action and learn how to use signs, symbols and other graphic-symbolic organizers to connect the action and its mental schema. Students also learn to assume the position of the other and to look at things from different perspectives. This is achieved by collaborative learning and by tutoring younger students. The issue of self-evaluation becomes one of the foci of learning. (p. 567)

I see a very close match between the developments within this research and Kozulin's description. For example, during the *Easter Egg Hunt* learners had to consider their goals (where to hide the treasure), their methods (what directions to give), and their means (what clues to put where). During the *Defuse the Bomb Challenge*, Learner C showed evidence of attempting mathematical signs and symbols through his drawing of clockwise and anticlockwise, and fractions. In addition, Learner A, being more capable than Learner B, assumed the role of peer tutoring her throughout the latter part of the helicopter challenge. Learners also gained symbolic tools and graphic organisers such as maps, grid references, and coordinate systems. Their collaborative discussion, although limited, had elements of taking into account another person's view. This happened in the study when Learner A accepted help from a peer to correct his Minecraft object.

However, more work needs to be done in modelling in terms of becoming explicit about the role of higher-order cognitive process, for example, by defining the higher-order skills deemed worthy of development during modelling tasks and by finding ways to operationalize these delineations for further research.

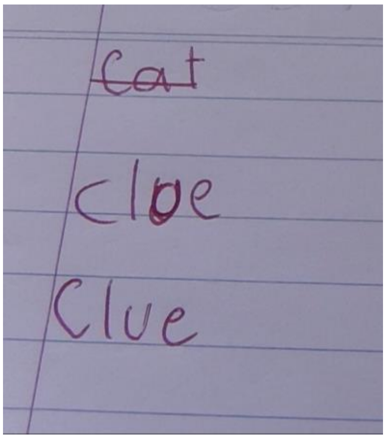
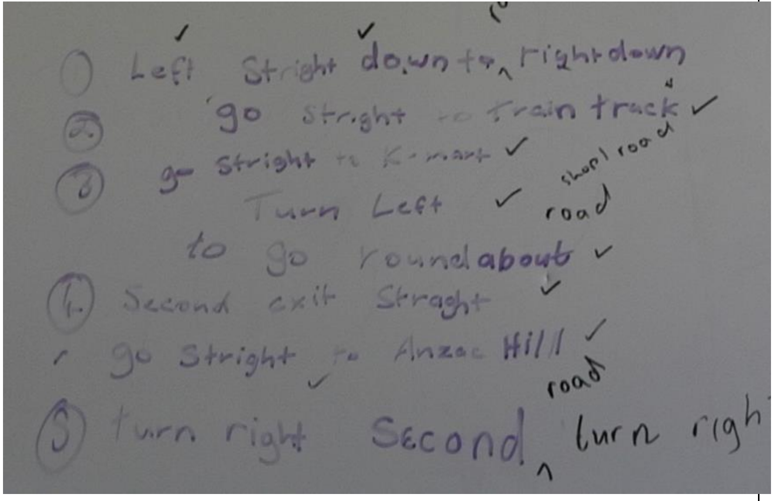
6.7.2.3 A suitable environment for life education

Modelling provides more than mathematical understanding. There are several examples of how the learners extended their learning into other areas, in particular, language development, appropriate use of technology, and imagination and play. As can be seen from the disability discourses, learners with SEN need more than knowledge, they need a curriculum that will enrich their lives and extend to them access to different aspects of society — the community, the workplace, the prevailing culture, and the mainstream school environment. In the foreground of their learning experiences is the need to increase their options in dealing with the world. Below, I list examples of how corresponding advances were made through modelling in this study.

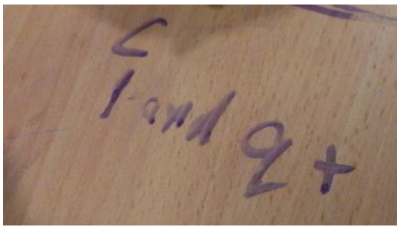
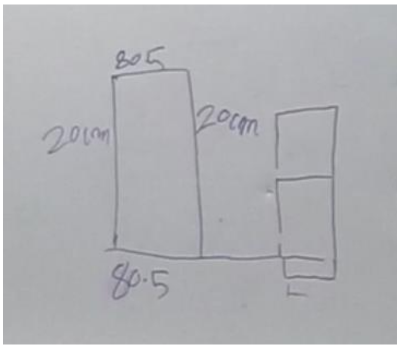
6.7.2.4 To mathematical infinity and beyond…

Considering that all three of the learners in the case study had significant speech and language challenges, the value of language and its accompanying features, such as imagination, humour and figurative speech should not be underestimated. These, and additional life outcomes are listed in Table 6.39.

Table 6.39 Examples of Life Outcomes achieved

Outcome	**Example**	**Challenge**
Figurative language	Learner: *I am in some place called Eureka.* Learner: *The clue says walk forward until you hit the wall, then turn right. I don't understand. Should we be hitting the wall? Why must we hit the wall*? *[shakes his fist into the air, pretends to hit with his fist.]*	**Easter Egg Hunt**
Spelling		**Easter Egg Hunt**
Writing	The blue writing shows the direction given to Learner A to follow, whereas the black shows some of the correction the class had to make to help Learner A get to the treasure. 	

Outcome	Example	Challenge
Making choices	Learner: *I will hide it in the girl's toilets. No one will get it there. Definitely the boys won't... in a tree... no, I think I'll put it in this room. If I put it in this room, no one will find it. I have a good spot for it, I can put it inside the kite. No one will look for it there.*	
Negotiating disagreements	Learner A: *I have a question. Where is the assembly hall?* Member from other group: *It did not fit in the picture so we left it out.* Learner A: *I can see the picture perfectly in the other picture. So that picture looks a bit better than that one. The assembly hall is a big thing.* Member: *It is our group turns not your group turns.* Teacher: *No, that group has the right to question your group.* Learner A: *So where is the assembly hall?* Member from other group: *[Swears] It's none of your business.*	
Interpreting symbols	Learner following a clue: *Miss, it says turn 90 ^{o} [ninety degrees] right. That's funny. We should turn 900 times right! What the heck?*	**Easter Egg Hunt**

Outcome	Example	Challenge
Developing symbols	 This photo is a learner's attempt to symbolise: clockwise, 1 ¼ turn.	**Defuse the Bomb**
Digital literacy	Teacher: *Doesn't matter. If you had to guess the prize of hot cross buns, how much would you guess? Take a guess. Maybe you can ask Mom tonight and we can tally things up again tomorrow. Let's take a guess for now. Hot cross buns would be about…?* Learner B writes down $5. Then tries to look it up on the Internet [Coles website].	**Easter Egg Hunt**
	Learner A: *How are we going to make a top view? We can't fly a helicopter?* Peer: *Google Earth.* Learner B: *[later on] Where is the garden?* Peer: *Look at the date. That was 2011. Even my home looks very different now to then.*	**Fly the Helicopter** **(Top View)**
Attempts at visual literacy		**Fly the Helicopter (Scaling in the classroom)**

Outcome	Example	Challenge
Play and imagination	Learner B: *I destroyed my wall.* Peer: *The wall of justice.* Learner A: *No, you have to say 'how'.* Peer: *How.* Learner A: *By a... by a rocket launcher - sfoof!* Peer: *This is the rocket launcher [moving block towards Learner B]* Learner A: *No! [blocking his face and laughing]*	**Fly the Helicopter (Building blocks)**
	Learner C: *No one touches mine.* Peer1: *I need my own fence.* Learner C: *Your own fence.* Peer1: *So I can put it around my bed. Can you make it for me?* Peer2: *But the zombies and creepers.* Peer 1: *Awesome! [for the made fence]* Peer 2: *This is our private city.* Peer 1: *No entry.* Peer2: *This is Minecraft city. Full of Minecraft things.* Peer 2: *I have a sword. Look Learner A, Look... I am your father. [Star Wars quote]*	**Fly the Helicopter (Minecraft)**
Multiple	Throughout the activities, learners worked with multiple	

Outcome	Example	Challenge
representations (UDL)	representations of the mathematical ideas. For example, during the *Easter Egg Hunt* learners verbally spoke directions, some learners wrote down directions, some drew maps, others moved through *Google Earth* following directions, and likewise reading clues around the school and following directions. Similar features can be found in the other two challenges as well.	
Challenging perceptions	Teacher: *My first question to you is why do we ask you to work in small groups?* Learner A: *So we can talk to one another.* Teacher: *So we can talk. What do we know about learning and talking?* Peer: *They don't go together well!*	

Table 6.39

6.7.3 Contribution to theory

6.7.3.1The role of personalised knowledge in representations

One of the patterns detected throughout the challenges is that, where possible, learners will used personal knowledge, at least as the starting point, for their thinking. This ties in with theoretical perspectives such as Vygotsky (1978) who argued that the ZPD is a place where a child's everyday concepts meet scientific concepts. Likewise, there is the neuroscience perspective (Section 2.5.2) suggesting that the brain operates from a memory template abstracted from previous experience, rather than operating directly with a given stimulus.

Similarly, Kahneman's model of System 1 and System 2 (Section 3.3.9) argue that we make decisions (and build models) through heuristics such as referring to that which is familiar or frequent to us.

The activities were set in a personal space, namely the learners' own school and town, and within the space the learners drew on personalised knowledge as the source for their solutions, in particular, knowledge that was frequent and had happy memories.

Several examples demonstrated that learners use personalised knowledge as the starting place for their thinking. Consequently, when learners were asked where they would like to hide the treasure there was a strong pull towards knowledge based on frequency, familiarity, and positivity. The "where" in this question is also indicative of the learners' starting places for their models, as they needed to give directions to that place, meaning that their choice would influence their models.

Learner A chose the garden as it was the place in the school that they had frequented regularly the year before.

Learner A: *Last year, when I was in the other class, we would go to the garden every day. We would go and feed the chickens.*

Learner C chose the airport in Adelaide, having just returned the day before from a holiday there.

Teacher: *I need you to find where we are going to hide the treasure.*

Learner C: *Yeah. mmm. Adelaide. I am going to hide my treasure in Adelaide. Where is this beach house?*

Moreover, every learner from the virtual group, with the exception of one, went straight to home and thereafter to the extended family's home (e.g. uncle), and the school.

Likewise, Learner C's choice of local shops was not made on the basis of logical justification such as the products they sell or comparative pricing, but based on the shop's connection to the familiar.

Teacher*:* *That is right. What do you want me to buy for $5 that would be the treasure?*

Learner C*:* *AAHH – This is tricky. Which shops?*

Teacher: *Coles or K-Mart.*

Learner C.: *OK Coles, because my sister works there.*

Similarly, Learner B chose hot cross buns as a prize because it reminded her of a special moment when she was with her mom.

Teacher: *Do you know how much hot cross buns are roughly? Have you seen the prize in the shops?*

Learner B: *I know mom got them for that day I wasn't here, when I didn't come to school. I had it for breakfast. But I did not see the prize. I think I was in the car waiting… or in the shop.*

A similar trend was seen in certain learners' drawings and reconstructions with foam blocks of the top view of the school. For example, Learner B seemed to base her representations on subjective memory and familiarity, rather than rendering a more exact copy of the buildings using the image in *Google Earth.* To this end Learner B's foam block structure had a very long walkway, reflecting how the school "feels" when one is walking along the walkway. Moreover, the building she frequented was both present and larger in her top view drawing, whereas she left out structures or buildings in which she had no classes. Moreover, Learner B wanted to measure only the building of the school which contained her class, and not the other structures.

6.7.3.2 The linking between sensory processes and higher cognitive reasoning

As indicated by Learner B's psycho-educational profile, she had ongoing challenges that were sensory in nature, including visual integration difficulties. This could be used to explain her need to swivel in the chair, rock on the swing, and her limited visual transport skills. Observing her learning challenges re-iterates the need to research the link between sensory processes and higher cognitive functions. This feeds into research around the role of the cerebellum as more than a sensory-motor coordinator, but as a modulator of higher cognitive processes (Murdoch, 2010, p. 858; Goswami, 2014) previously discussed in Section 2.5.2.

6.7.3.3 Contribution to design theory

The very nature of DBR is to question the relationship between task design and impact on learning from many different angles. To illustrate, DBR questions the nature of the task in relation to the agenda of the researcher or teacher, the activity of learners, the engagement of learners, and the effectiveness of learners' learning. More recently, the NMT brain map has added another dimension, namely, the nature of the task in relation to the physiology of the learners, in particular the learners' brain structures and functions. Put differently, how does brain scan affect our task designs? In Learner C's case, his frontal cortex showed a lot of red, and he had features lower down in his brain that were also vulnerable. Perry's NMT theory suggests that educators move from the bottom parts of the brain upwards. What does this mean for design? I pointed out that during the challenges there were several activities that Learner C engaged in and was to a large extent able to self-regulate, concentrate and be involved in for an extended period of time, such as *Google Earth*, Minecraft, or flying the helicopter. In other words, he can learn and concentrate and be involved, but it is clearly dependent on the features of the activity. To illustrate, he rejects frontal cortex tasks such as writing or measuring and embraces sensory tasks — touching, turning the dial, moving through *Google Earth*, and rolling the measuring wheel. What would lessons catering for the lower parts of the brain look like? Does it mean that modelling has to been integrated into an age-appropriate play-based learning environment? Does it mean that modelling challenges have to be more sensory (tactile, kinetic, visual) in nature? These relationships need to be further explored to help capitalise on Learner C's strengths and personalised interests as a bridge towards gaining inroads into his cortex over time.

6.7.3.4 Contribution to theories on collaborative learning

Features of this research relate back to work being done on understanding collaborative learning processes and group cognition. To illustrate, Learner A's progression from being insular to becoming a peer tutor in an autocratic way, and slowly growing in his inclusivity of others' opinions, connects to work such as Damon and Phelps' (1989) categories of collaborative learning (peer tutoring, co-operative learning, and collaborative learning) and the contrast between these categories in terms of equality and mutuality of engagement (Section 3.3.7).. The study also confirms some of Webb's (2013) list of incidences that undermine group performance (Section.3.3.7). In particular, teasing and name calling, and disengagement from the group proved relevant to this study. Moreover, there were examples where learners' individual products outperformed group products and yet there were instances where group performance increased individual performance. For example, both these processes were seen during the foam block activity where learners had to construct a structure of the school as seen from top view. One individual's performance outperformed the group's performance in detail and proportionality. On the other hand, when Learner A took his peer's suggestion into account, he produced a more suitable solution to the one he proposed beforehand. These dynamics and their susceptibility to perceptions of power of different group members need further research. In addition, mediation is a form of collaborative learning. Work such as Tzuriel (2000) investigated mediation by learners to other learners. There is scope to explore mediation from additional angles, for example, how the frequency of mediation relates to the learners' cortical modulation ratio in Perry & Pollard's (2008) work. I would anticipate that the lower the cortical modulation ratio, the greater the intensity and frequency of the mediation required by the learners.

6.8 The primary research question

I noted in Chapter 1 that the purpose of the tasks and their attached secondary research questions is to help me answer the primary research question, where the primary research question of the study is: *"How can mathematical modelling be used with learners with SEN to improve their understanding of mathematics?"*

How then can mathematical modelling be used with learners with SEN to improve their understanding of mathematics?

I used data from Feuerstein's list of cognitive functions (Section 2.7.3) and Perry's brain map (Section 2.4.3.2 and Section 4.5.1.1) to show that learners with SEN are different to typical learners in that they have underdeveloped and dysfunctional brain structures and functions. For this reason, it is not sound practice to assume that learners with SEN will learn mathematics simply be engaging with modelling tasks, neither is it acceptable to exclude learners with SEN from modelling on the basis that their higher-order cognitive processes, and often social processes, needed for group work are vulnerable. I showed that learners with SEN can learn mathematics through modelling provided that their model-building experiences are mediated to help them manage with mathematizing the content, construct the concepts, and deal with the collaborative expectations. Accordingly, I suggest that educators become members of the small groups to provide a way of mediating situations until the learners are ready to "mediate" one another.

I also suggest that we start aligning brain maps with designs. For example, this study suggests that the learners with dysfunction lower down in the brain seek out somatosensory input and that modelling tasks that are more "active" in design may prove more beneficial for their learning. Consider, for example, how often Learner B swivelled in the chair or rocked on the swing. Likewise, Learner C was moving frequently, singing, dancing, banging on the furniture, and trying to catch the fish in the fish tank. Instructional designs such as reading short clues while hunting for treasure around the school, flying a helicopter to coordinates on a grid reference, moving around town in *Google Earth,* and turning a dial kept them engaged and on-task, in contrast to more "sit down and write" tasks. Also, the educator will need to get to know the learners and use designs that relate to their personalised knowledge and memory. To illustrate, the Minecraft exercise was really the folding of 3D nets, mostly into cubes. Yet, the learners were enthralled by it because it was a "Minecraft cauldron", a "Minecraft treasure chest" and a "Minecraft creeper". The mathematics became meaningful to them when it entered into their world of interest. Likewise, Learner B really wanted to measure her part of the school. She was not interested in the other parts.

Furthermore, considering the wide range of learners' capabilities in mathematics typically found in learners with SEN, the designs have to be open-ended, or flexible, enabling very weak learners to enter into the problem, and enabling more capable learners to be extended, without the strong learners feeling bored and/or the weaker learners becoming despondent.

Accordingly, I propose the following localised theory of instruction:

- Use modelling as a ZPD and actively mediate higher-order reasoning and cognitive processes.
- Design somatosensory modelling tasks for learners with dysfunction in their lower regions of the brain.
- "Personalise" the mathematics by finding connections between the mathematics and the learners' interests.

- Provide learners time on their own to think through the problem before collaboration.

6.9 CONCLUSION

Chapter 5 presented an analysis of the data and a discussion of each of the research questions. It was divided into three sections. The first section described the cycles of the design, its implementation, and reflection on its implementation and consequent modification. In the second section, three cases were discussed in relation to the characteristics, the processes, and the representations of the learners. In other words, data were related back to the primary and secondary research questions.

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

CHAPTER 7

7.1 INTRODUCTION

This chapter begins with a summary of the research and a discussion of findings. It also describes the limitations of the study and concludes with recommendations for further research.

7.2 SUMMARY

Direct teaching's current levels of attainment in special needs environments have been well documented and demonstrated through research. However, to only allow for direct learning experiences without giving modelling a proper place is a form of deficit thinking akin to imposing limits on learners from without in response to their learning challenges. Consequently, the purpose of this research was developing inclusive practices, not in terms of the placement in learners, but in terms of looking at the quality of learning experiences made available for learners with SEN and how to support this cohort of learners in accessing more diverse materials. Significantly, this is known as the *Access to Curriculum* dilemma. The *Access to Curriculum* dilemma has another dilemma embedded into it, which is the *Developmentally Delayed or Developmentally Different* dilemma, whereas developmentally delayed perspectives suggest that learners with SEN are predominantly the same as mainstream learners, but that they need to learn at a lower and at a slower pace. In contrast, the "developmentally different" group see learners with SEN as different to their peers, and therefore in need of more specialised instructional intervention. The argument in this study is based on the latter side, which is the developmentally different perspective. Evidence for my position is found in the work of Feuerstein's "invisible" construct of cognitive deficits and Perry's "visible" brain maps showing definitive functional and structural dysfunction across the four dominant brain regions of learners with SEN. It should be emphasised that having different brain mechanisms should not affect a person's dignity and worth as a human being, and that both theorists (Perry and Feuerstein) argue that these brain mechanisms can be strengthened to improve the learners' functioning. For this reason, recognising difference in this study is not for the purpose of classifying or labelling individuals, or to justify segregated and reduced curricular activities, but it is used as the starting point to develop solutions for increasing the capacity of learners with SEN to engage with mainstream learning options. Accordingly, after studying the critical features of modelling, I concluded that modelling was a potentially rich platform for developing learners' social and higher-order cognitive skills, and that it offered several additional benefits to learners with SEN that are life-enhancing. My decision contrasts to educational philosophies that promote waiting for the learners to have these skills before engaging in modelling or, alternatively, believing that modelling in itself will spontaneously cultivate these skills in learners without additional specialised input. In contrast to the latter two positions, I argued that teachers will have to modify the learners' cognitive structures and functions in addition to providing developmentally appropriate yet challenging modelling tasks as per inclusive promoting practices. For the purpose of modifying the learners' cognitive structures, I proposed that educators view the modelling environment as similar to Vygotsky's ZPD, with a specific focus on developing emergent psychological tools in learners through joint activities from modelling. Although Vygotsky (1978) had a broad range of psychological tools, I limited these "tools" to Feuerstein's list of 28 cognitive deficits or cognitive functions. I chose these functions as they are closely attuned to the modelling phases expected of learners as they solve challenging mathematics problems. To clarify, the input phase of Feuerstein's list of functions corresponds to the problem identification phase in modelling, the elaboration phase corresponds to model building and refinement, and the output phase corresponds to communication and justification of the model. I illustrated through three case studies how I mediated learners' modelling processes and how these mediations increased the mathematical quality of the learners' models. To assess the learners' progress, I used the philosophy of formative evaluations, or dynamic assessments, where teaching-learning-assessing and mediation blended together. At the same time, I included a more standardised matrix used in mainstream curricula. Careful observation of the learners' progress shows that dynamic assessments produce more substantial evidence of learning in a SEN context than does movement along a standardised matrix. To explain, over the four weeks of intervention, learners did not progress along the standardised matrix, yet there is evidence to suggest that they are learning worthwhile mathematical content and building stronger models through joint activity. At this point, I must clarify that the models were never "built for them", but that the intention was to strengthen their cognitive tools (for example, their ability to focus or to organize information by recording it in writing), which in turn enabled them to produce more powerful models on their own. Put differently, they still had to solve the problem and construct their model. This was not done for them.

7.3 RESEARCH QUESTIONS AND RESEARCH AIMS

The primary research question of the study was: *"How can mathematical modelling be used with learners with SEN to improve their understanding of mathematics?"*

To answer the primary research question, I pursued a series of sub-questions that at set stages in the research were attached to specific research tasks. The sub-questions were:

- How do the learners' characteristics taken from their psycho-educational profiles affect their modelling?
- How do the learners' processes, solely in respect to Feuerstein's cognitive functions, affect their modelling?
- What evidence of learning could be found in the analysis of learners' reasoning and representations over time?
- How did the learners' learning correspond with the proposed learning trajectory?
- To what extent did modelling benefit and/or impede the mathematical learning of learners with SEN? An evaluation of the design against Tyler's (2013) general learning principles.
- How viable is modelling as an instructional approach in a SEN classroom based on an **analysis of learning characteristics, processes, and representations in mathematical modelling of middle school learners with special needs?**

Learners' psycho-educational profiles affect their modelling in varied ways. On the more negative side, learners who have difficulty with social situations, who at times upset their peers, and learners with low concentration spans had difficulty entering into tasks and needed mediation to stay on task. Likewise, learners with behavioural challenges became disruptive during set activities. In other words, learners responded differently to modelling, and found different aspects of modelling challenging, depending on the strengths and vulnerabilities of their learner profiles. For this reason, as per the secondary research questions, it became important to mediate where the learners' cognitive functions were underdeveloped. Mediation, through a type of dynamic assessment and intervention, helped the learners benefit more from their mathematical learning. Evidence for this was found in their representations, showing how mediation facilitated the learners in constructing richer, more elaborate models.

On the positive side, in spite of their vulnerabilities, most learners were engaged in the tasks and "had a go". To a large degree, the original hypothetical learning trajectory was followed, and for the most part the actual learning experiences compared positively to Tyler's (2013) five criteria of good learning principles from a learner perspective. Positive outcomes include that learners were engaged in the tasks, self-reported that they enjoyed most of the challenges, and that, in addition to mathematics, they achieved a range of other outcomes relevant to life.

Based on the outcomes of the study when compared against Tyler's principles, I concluded that modelling is viable in a special needs environment. Its viability as an instructional approach lies in its ability to inform inclusive decision-making processes and in preparing learners for inclusive mainstream classrooms and curricular activities. In other words, modelling is also suitable as a tool for cognitive education and for providing learners with SEN with rich, broad learning attainments across several platforms, of which mathematical learning, literacy (general literacy, digital literacy, and mathematics literacy), and functional life skills, including communication and practical applications of mathematical concepts outside of school, all form a part. Involvement in modelling, which supports larger disability discourse outcomes and is relevant to real-life situations and applications outside of the school context, was emphasised.

In working through the list of secondary research questions, I conclude that I reached several of my research aims, which were to consider how modelling could be used as a tool for inclusive teaching, as a form of education in which the theories of Feuerstein *et al.* (1988, 2010) and the related theory of Vygotsky (1978) could be applied in the context of modelling to strengthen higher-order cognitive functions through joint activity, and as a way to improve my own pedagogical knowledge and classroom approach with respect to how learners with SEN learn worthwhile mathematics through modelling.

At the end of this study, my response to the primary research question of the study, which was, *"How can mathematical modelling be used with learners with SEN to improve their understanding of mathematics?"* is as follows:

> By the end of the study I developed a localised instructional theory informed by the following general design principles:

1. Use modelling as a ZPD and actively mediate higher-order reasoning and cognitive processes.
2. Continue to harvest personalised knowledge schemes as a bridge into mathematical content.
3. Rely more on somatosensory design techniques when brain maps indicate significant dysfunction in the lower parts of the brain and an underdeveloped cortex area.
4. Continue to monitor research into the cerebellum as a modulator of higher-cognitive processes and consider its implications for design.
5. Consider how to develop peers to become active mediators within the group.
6. Provide learners time on their own to think through the problem before collaboration.

7.4 LIMITATIONS

It was a localised study — very small in scope, and very personalised in design and support. Clearly, a longer period would enable a much more valid appreciation of how learners with SEN respond to modelling. Yet, support for learners benefiting from modelling in terms of their mathematical learning through mediation is present. However, the limitations do indicate scope for further research. These and other limitations are addressed within the context of recommendations for further research in the next section.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

The lack of generalizability of qualitative research is, at once, a considerable weakness in terms of scalability of designs and instructional approaches, yet at the same time a great strength in that it gives opportunity to study in depth a small number of learners with complex learning challenges as they use modelling in a learning environment. Considerably more research should be done into modelling and learners with SEN to provide opportunities for collecting, collating, and evaluating data towards planning for improved designs and increased quality of learning and to articulate some of the complex issues involved in this work. The most important reason to continue research into modelling is to open up new avenues of learning for learners with SEN instead of closing them down. With this in mind, it is important that we emphasise the need to understand mathematical modelling knowledge construction processes in the context of developmental delays, typical learning trajectories, and best-practice principles of teaching and learning in a special needs environment.

Further options for research, from within this study include:

- How do we effectively use the functional brain as a tool in instructional design in SEN classrooms? Do all learners with dysregulation in the lower parts of the brain, and with very underdeveloped upper areas, seek out somatosensory learning experiences? How do we apply the link between sensory processes and higher-order reasoning skills in future lesson plans? Is an age-appropriate, play-based modelling design a potential way forward in SEN classrooms?
- What are the main cognitive functions that are required by modelling? How should these be defined and operationalised to accommodate further research on the ability of modelling to strengthen higher-order reasoning processes?
- How do we effectively use peers to mediate higher order reasoning, as opposed to task completion?

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Addendum A: Ethical clearance approval from the University of Stellenbosch, South Africa

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Approval Notice

Response to Modifications- (New Application)

26-Aug-2013
SCOTT-WILSON, Rina

Proposal #: HS945/2013

Title: **An analysis of learning characteristics, processes and representations in mathematical modelling of middle school learners with special needs**

Dear Mrs Rina SCOTT-WILSON,

Your **Response to Modifications** - ***(New Application)*** received on **21-Aug-2013**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **21-Aug-2013** and was approved.
Please note the following information about your approved research proposal:

Proposal Approval Period: **22-Aug-2013 -21-Aug-2014**

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**HS945/2013**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 0218839027.

Included Documents:
Application for permission
Curriculum Vitae
Assesment of Cognitive skills
Assent form
REC Application
Coding categories
DESC form
Research proposal
Field work notes
Ethics clearance - Australian
Interview guide
Informed consent
Brain map

Sincerely,

Susara Oberholzer
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Addendum B: Ethical clearance approval from the Depart of Education, Nothern Territory, Australia

Northern Territory Government

DEPARTMENT OF EDUCATION

Level 14 Mitchell Centre
55-59 Mitchell Street, Darwin
Postal address GPO Box 4821
DARWIN NT 0801
Tel (08) 8999 5829
Fax (08) 8999 5788
Researchapps.det@nt.gov.au
Our ref DET2013/138-85
EDOC2013/4846

Mrs Rina Scott-Wilson
Centralian Middle School
Via email: Rina.Scott-Wilson@ntschools.net

13 December 2013

Dear Mrs Rina Scott-Wilson

RE: RESEARCH APPLICATION: "An analysis of learning characteristics, processes and representations in mathematical modelling of middle school learners with special needs"

I am pleased to advise that your application to conduct the above research has been approved by the Research Advisory Committee (RAC).

Please note that the decision to participate in this project will be at the discretion of the respective school principal and relevant individuals. Please provide a copy of this letter to the school principal and liaise directly with the principal to reach a mutually convenient time for conducting the research so that disruption to students' learning is minimised.

I advise that it is mandatory for people who have contact or potential contact with children in certain areas of employment hold a working with Children Clearance Notice. Please ensure you satisfy this requirement as per http://www.workingwithchildren.nt.gov.au/.

The Department is interested in the findings from your research and as such I look forward to receiving a copy of the final report. If you require any further assistance you may contact the Research and Evaluation Team on 89995829.

Yours sincerely

Kevin Gillan

Kevin Gillan PhD
Chairman Research Advisory Committee

www.education.nt.gov.au

Addendum C: Ethical clearance approval from the Central Australian Human Research Ethics Committee

CENTRAL AUSTRALIAN HUMAN RESEARCH ETHICS COMMITTEE
Centre for Remote Health
PO Box 4066 Alice Springs NT 0871
Ph: (08) 8951 4700 Fax: (08) 8951 4777
Email: cahrec@flinders.edu.au

Ms Rina Scott-Wilson
Centralian Middle School
56 Milner Rd
Alice Springs NT 0870

13th November 2013

Our Ref: HREC-13-167

Dear Ms Scott-Wilson

RE: Ethics Application – Approval

The Central Australian Human Research Ethics Committee (CAHREC) Chair has considered your response to the Committee's request for further information about your research project **'An analysis of learning characteristics, processes and representations in mathematical modelling of middle school learners with special needs'.**

The Chair agreed that this project now meets the requirements of the National Statement on Ethical Conduct in Human Research.

The Chair decided to **grant approval** for your project to proceed.

The period for which approval has been given is from the date of this letter until the **31st January 2015**. If you do not complete the research within the projected time please request an extension from CAHREC.

Ethics approval is contingent upon the submission of an annual Progress Report and a Final Report upon completion of the project. Please make a note of the following dates as failure to submit reports in a timely manner will result in your ethics approval lapsing.

Your reports are due on:

12th November 2014

31st January 2015

Copies of the report form can be downloaded from the CAHREC website.

Yours sincerely

Chris Schwarz
Secretariat Support
Central Australian Human Research Ethics Committee