Grade 4 learners' anxiety during automatisation of multiplication facts in computer-assisted instructional environments

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Dissertation submitted in fulfilment of the requirements for the degree *Magister Educationis* in Learner Support at the North-West University

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Graduation May 2018

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Declaration

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

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2017-11- 13

Abstract

As we live in a world that constantly involves the application of mathematical ideas and mathematical thinking, reasoning and problem solving, performances in Mathematics remain a key indicator in determining the effectiveness of school systems. With regard to the South African school system, the World Economic Forum's (WEF)'s "Global Information Technology Report - 2016" paints a bleak picture of the quality of Mathematics education in South Africa. Out of 139 countries assessed, this report ranks the quality of South Africa's Mathematics education at an alarming last place. This (last) position has not changed since 2011.

One of the aims of Mathematics education in South Africa, as put forward in the National Curriculum, is for learners to "deal with any mathematical situation without being hindered by a fear of Mathematics" through "teaching and learning of Mathematics confidence and competence". Hence, concern regarding the increasing anxieties surrounding and accompanying learning and performance in Mathematics escalates. Basic computational fluency (the rapid recall or automatisation of computational facts *with* or *without* conceptual understanding) is considered a pre-requisite skill to facilitate higher-order processing in problem solving. Anxieties regarding acquiring computational fluency may therefore inhibit the optimal development in mathematical thinking, reasoning and problem solving.

Against this background and in contrast with traditional classroom practices of pen-and-paper time-drilled exercises to acquire computational fluency, the study interprets (through qualitative investigation) Grade 4 learners' anxiety experiences while acquiring automaticity regarding multiplication facts in computer-assisted learning environments. By exposing a sample of Grade 4 learners alternatively to two fundamentally different learning environments ('computer drill-and-practice exercises' - CDP and 'digital game-based learning - DGBL environments'), the participants' anxiety experiences while attaining automaticity regarding multiplication facts, could be investigated. Anxiety as academic emotion was observed on a continuum of emotional manifestations, ranging from averseness (anxiety) to attractiveness (confidence) in situations where mathematical thinking and reasoning is required. In the study, this phenomenon is referred to as *anxiety↔confidence* valence.

The current study does therefore not put forward theory or advanced existing theory, but rather interprets the anxiety experiences of Grade 4 learners (if any) to understand the anxiety↔confidence valence. Through these interpretations, recommendations and strategies to consider towards improving the automaticity skills regarding multiplication facts of Grade 4 learners, were put forward. The findings confirmed that CDP environments are more likely to foster feelings of anxiousness than those learning experiences in DGBL environments.

In counteracting the devastating effect of over-emphasising pen-and-paper drilled exercises, (as revealed in literature) DGBL games should be favoured over and above CDP games as the latter was found to create anxiety or aggravate existing Mathematics anxieties. Furthermore, the choice of

DGBL game needs to take the personality as well as the interest of individual learners into account. Therefore, the anxious and worrisome thoughts stemming from undesired methods of automatisation that may be carried well into adulthood, can be limited if not eradicated.

Key words: Mathematics anxiety; anxiety ↔ confidence valence; computer-assisted instruction; computer drill-and-practice (CDP) learning environment; digital game-based (DGBL) environment; computational fluency; automaticity; rote memorisation and mental Mathematics.

Acknowledgements

The past four years have been an extended period of intense learning for me, not only in the field of Education, but also on a personal level. Writing this dissertation has had a huge impact on me and I would therefore like to reflect on the people who have supported and assisted me so much throughout this period. “When mom has an itch, everyone needs to help scratch”, my husband rightfully and frequently noted throughout the many years of our marriage. This thesis was certainly no exception. I humbly acknowledge those who have helped to scratch, as well as those who suffered due to my own frustrations in not being able to reach all those areas where the “itch” originated from.

First and foremost, I am profoundly grateful to both my study leaders who stepped up when no other professional “scratchers” were available. Thank you for your invaluable guidance and providing me with the tools to continue “scratching” by following tried and trusted methods and by not following my self-devised intuitive directives.

In addition, heartfelt thanks goes to my colleagues who willingly freed my hands (for “scratching”) by taking over some of my roles and responsibilities at work during times of acute itching. Last, but not least, to my beloved family - the “itch” may have caused serious distress and discomfort, if it were not for your loving support. Everyone, from the youngest members who had to forfeit visiting “ouma” and “oupa” to the eldest members (including my beloved father, who passed way halfway through the journey), his scratch being kept alive via my dearest mother.

The entire “itch” would however be excruciating without the gentle nudging from my best friend and husband. Thank you for sharing my passion for the intellectual and psychosocial well-being of children. You stayed by my side throughout the journey… always ready to “scratch” when the “itch” became unbearable, or to take over my duties so that I could “scratch….and scratch” ……relentlessly!

Thank you very much, everyone!

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Orientation

"The importance of automaticity becomes apparent when it is absent."
(Wong & Evans, 2007, p. 91)

1.1 Background to the Problem Statement and Intellectual Conundrum

We live in a mathematical[1] world that constantly involves the application of mathematical ideas and mathematical thinking, reasoning and problem solving. Performances in Mathematics is a key indicator to assess the performance of the South African school system (Reddy, Van der Berg, Janse van Rensburg, & Taylor, 2012). Reddy et al. (2012) point out that the ill-attainment of the Mathematics curriculum requirements could, over time, result in a critical shortage of professionals in, among others, the fields of medicine and financial management. This statement led to the question of whether and to what extent do South African learners fulfil the curriculum requirements for Mathematics.

In the speech delivered by the Minister of Basic Education at the Announcement of the 2015 NSC Examinations Results at Vodaworld in Johannesburg on the 5th of January 2016, Mrs Angie Motshekga (MP), announced that due to the increase in candidate numbers, the *number* of National Senior Certificate candidates who passed Mathematics increased. The pass *percentag*e, however, decreased (Motshekga, 2016). When this statement is viewed against the National Senior Certificate's Mathematics pass rates (percentage) since 2013, certain realities regarding Mathematics performance in South African school system are revealed.

Firstly, between 2013 and 2015, the pass rate in Mathematics decreased from 59,1% in 2013, to 53,5% in 2014 and to 49,1% in 2015 (Motshekga, 2016). In 2010 already, a policy, *Towards the Realisation of Schooling 2025* (DBE, 2009) set out a strategy to increase the matric pass rate in Mathematics to around one in three (33,3%) by 2025, as only one in seven (14,29%) learners met the minimum requirements for Mathematics in 2009. Almost halfway into the implementation period of the abovementioned strategy and the increase so far, up to 2015 is only 1,83%. In reality this constitutes nothing more than a drop in the bucket, as the situation described as the '*one in seven',* can as yet not even be changed to *'one in six'*. Many South African learners therefore still experience difficulties in applying mathematical knowledge, concepts and skills in everyday Mathematics tasks as stated by Bauer (2013) and Reddy et al*.* (2012).

Secondly, in addition, both South African grade 5 and grade 9 learners ranked 48th out of 49 participatory countries in the Trends in International Mathematics and Science Study (TIMSS) in 2015 (Mullis, Martin, Foy, & Hooper, 2016). Reddy et al. (2015) in a summative review (trend analysis) of the South African TIMMS results over the past 20 years, emphasise that 75% of South African learners only

[1] Mathematics (with capitalisation) refers to the school subject whereas mathematics (without capitalisation) refers to the abstract science of number, quantity, and space.

achieved results in the low benchmark category. In reality this boils down to the fact that 75% of South African learners at Grade 9 level in 2011 could only acquire the following Mathematical skills: basic knowledge of whole numbers, decimals and operations, and graphs while learners at the high and advanced benchmarks are able to problem solve at high levels, reason with geometric figures and analyse graphical data (Reddy et al., 2015).

Thirdly, although minimal, some improved learner performance in Mathematics by South African learners over the past twenty years could be witnessed (Reddy et al., 2015; Frempong, Yu & Winnaar 2015). Due to this slow improvement rate, both these Human Sciences Research Council (HSRC) reports, revert attention from the conventional and tangible factors ascribed to negatively impact on learners' academic performance (for example resources, teachers' qualifications and experience, language of teaching and learning and class size) to less tangible factors such as learners' aspirations, expectations and motivation. Frempong, Yu and Winnaar (2015) state that the latter aspects previously received minimal recognition in the South Africa's education policies - even in the more recent policy that envisages improved schooling by 2025, motivational factors were not even mentioned (DoBE, 2009).

The authors of abovementioned HSRC reports, together with the team headed by Reddy (2015), promote pedagogical approaches where learners are supported in gaining confidence in Mathematics, which is envisioned to result in improved learner performance (Frempong, Yu & Winnaar, 2015; Reddy et al., 2015). These pedagogical approaches look beyond curriculum delivery and also describe detailed interventions regarding violence and bullying, realistic expectations, differentiated support strategies in schools with and without school fees, teacher and learner attendance, punctuality and collaborative support among schools, communities and households in motivating learners in understanding the value of mathematics (Reddy et al., 2015).

The World Economic Forum's (WEF) "Global Information Technology Report - 2015" also focuses attention on the quality of Mathematics education in South Africa (Baller, Dutta & Lanvin, 2016). Out of 139 countries assessed, this international report ranks the quality of South Africa's Mathematics education at an alarming second last place (Frempong, Yu & Winnaar 2015).

It also needs to be asked whether South African Mathematics teachers fully comprehend, or ever will comprehend, the actual aim of Mathematics education, as put forward in the National Curriculum (CAPS) (DoBE, 2011b). One of these aims is for learners to "*deal with any mathematical situation without being hindered by a fear of Mathematics*" through "*teaching and learning of Mathematics confidence and competence"* (DBE, 2011b, p.8).

It is against this background that there is a concern regarding the lack of confidence in Mathematics and how the impact thereof on the learning and teaching of Mathematics could escalate. This concern is in agreement with Wu, Barth, Amin, Malcarne and Menon (2012), who plead for more research on the manifestation of Mathematics anxiety - especially in younger learners. Furthermore, it is unclear how and if current teaching and learning strategies regarding basic computational skills for Grade 4 learners (for example multiplication) could lead to confidence in transferring the acquired skills to mathematical problem solving. This study interprets the teaching and learning processes of multiplication facts and, in particular, the *anxiety↔confidence* valence of Grade 4 learners in the process of automatising multiplication tables facts. The term “valence” is used to characterise and categorise specific emotions; denoting intrinsic attraction (positive valence) or aversion (negative valence) of an event, object, or situation. Throughout this study a symbol (↔) was used to indicate the valence between the two different academic emotions: anxiety and confidence.

Computer-assisted instruction (CAI) is defined as interactive instructional techniques whereby computers are utilised to present learning material and monitor the learning that takes place. CAI uses a combination of texts, graphics, sound effects and video or animated material to enhance the learning process (Fuentes, An & Alon, 2014). Since the turn of the century researchers started to confirm that computer-assisted instructional environments could result in learners’ heightened enthusiasm about and engagement with Mathematics tasks and, doing so, the anxiety experiences could be reduced (Nordin, Tahir, Kamis & Azmi, 2013; Zhang, 2001). This study therefore also aim to understand whether alternative teaching and learning strategies in the form of computer-assisted instruction could lead to Grade 4 learners’ enhanced confidence when automatising multiplication facts.

From the exposition of the proposed research problem, a number of complex social realities that span across different disciplinary fields are revealed. Mathematics education, affect in Mathematics education and Computer-assisted Instruction (CAI) in Mathematics education seem to be underlying issues within these realities. To provide a conceptual framework for the intended study and place it within the larger educational context, a concise review of relevant literature follows.

1.2 Review of Literature on Computer-Assisted Instruction (CAI) and Role of Affect in Mathematics Education

1.2.1 Introduction

Wolfram (2013) iterates that although the world is more mathematical (quantitative) than ever before, Mathematics Education is in global turmoil and learner performance is deteriorating. Traditional assumptions about *who* should study *what* Mathematics and *why* have been revisited over the past decade, urging on and emphasising the need for research into the role of *affect* in Mathematics education and the subsequent impact thereof on performance (Clements, 2013). Stuart (2000) asserts that Mathematics anxiety does not originate from the beliefs and attitudes of mathematics itself, but from the way in which Mathematics is presented in class, or have been presented to teachers when they were still at school. The researcher follows this premises by examining not only the *anxiety↔confidence* experiences of learners in various situations where they have to automatize multiplication facts, but also by examining the *anxiety↔confidence* through the lens of co-manifested negative academic emotions of hopelessness, shame, anger and boredom as well as positive academic emotions of joy, pride, relief and enjoyment (Pekrun, 1992). Pekrun, Goetz, Titz and Perry (2002) coined the term academic emotions to describe the feelings or emotions (affect) directly linked to learning, as they state that learners experience a variety of emotions in academic settings that influence their learning behaviours in one or more subjects. The major academic emotions observed were enjoyment, hope, pride, anger, anxiety, shame, hopelessness, confidence, relief and boredom.

According to the 2016 World Economic Forum report rapid advances in technology have also started to dictate the direction Mathematics research as well as Mathematics education should take (Baller et al., 2016). Locally, it stands to reason that at least 49 percent of the population regularly make use of information technology – mainly through the use of mobile phones (Baller et al., 2016). The aforementioned report also states that on 7- point scale, internet usage in schools for instructional purposes is rated at an unacceptable level of 3,2; below the mean of 4.6 of 139 countries surveyed (Baller et al., 2016). In 2011, only 10 percent of South African schools had computer centres fitted with computers in working order (DoBE, 2011a). South Africa's Mathematics education can therefore not provide the technological curriculum enhancements for which a large portion of learners are prepared through regular use of technology and internet outside school. At classroom level technology (CAI) widens the gap between learners with digital access, and those without access, when the use of technology at school level should in actual fact be narrowing this gap (Woodrow, 2003). Despite this widening in the 'digital divide', both internationally as well as on the home front, the advantages of using technology, especially in educational games (in terms of learning and understanding) remain incontestable (Felicia, 2009).

In response to the research problem, three overarching constructs formulate the conceptual framework of this study; Mathematics education (referring specifically to computational fluency), the role of affect in Mathematics, and Computer-assisted Instruction (CAI) in Mathematics education. The interrelated aspects of these constructs are discussed below.

1.2.2 Computational fluency and automaticity

Generally, basic computational fluency is a pre-requisite skill to facilitate higher-order processing in problem solving (Loveless, 2003; Smith, 2010; Westwood, 2003). The process whereby computational fluency is attained by means of rote memorisation of number facts (manipulation of mathematical symbols without conceptual understanding) is referred to as automatisation (Baroody, 2006; Boaler, 2015). Wong and Evans (2007) contest that Mathematics lessons are stalled due to learners who have not attained automaticity in the rapid recall of number facts from memory. To these authors conceptual understanding of number facts before memorisation are viewed as redundant; it apparently does not contribute to overall mathematical proficiency.

Both Lehner (2008) and Westwood (2003) remind us that where time-drilled practice may be regarded as essential for some learners to acquire fluency, it can cause other learners to lose confidence in their abilities to perform in Mathematics tasks causing them to foster negative affective experiences with Mathematics and, in turn, inhabit anxious and worrisome thoughts about the subject. Boaler (2015) cautions about the far-reaching consequences of time-drilled practice and assessments by stating that the more rote memorisation is stressed, the …"less willing they [learners] become to think about numbers and their relations and to use and develop number sense" (Boaler, 2015, p. 2). Scarpello (2007) also cautions about timed tests as tools for developing mathematical fluency as these practices may undermine a learner's natural thinking process which could lead to negative beliefs and attitudes towards mathematics. Wong and Evans (2007) furthermore explain that without automaticity a learner's focus will remain on applying computational strategies rather than solving the problem. Chinn (2013) and Kennedy, Tipps and Johnson (2008) insist that conceptual understanding and meaningful strategies in practicing the different operations (plus, minus, multiplication and division) can lead to automatisation and improved computational fluency skills without the harmful anxieties created by attaining automaticity by means of rote memorisation (Boaler, 2015). This author argues that Mathematics is the main cause of tertiary students' general academic anxieties and these fears originated when having to memorise Mathematics facts (specifically multiplication tables) and having to provide proof of the knowledge thereof (not the understanding) by means of time-drilled assessments before the age of nine years.

Barnes (2005) and Barnes and Venter (2008) commented on the teaching and learning strategies in Mathematics generally found in South African classrooms. They argue that a formal and traditional authoritarian approach still prevails and learners are afforded little opportunity for contextual and authentic learning. In contrast, the National Curriculum promotes "active" and "critical learning", opposed to "rote and uncritical learning of given truths" (DoBE, 2011b, p.7). With regards to learning of multiplication facts *mental mathematics*[2] however still relies heavily on memorisation through drills and practice with formative timed tests to monitor learners' recall of facts (DoBE, 2011b). At classroom level, the South African prognosis is even worse as learners in the foundation phase are often taught by under-qualified or unqualified teachers, resulting in an "impoverished curriculum being delivered with poor foundational competencies resulting in learners being ill prepared for Mathematics in the higher grades" (Venkat & Essien, 2011, p.12). Furthermore, learners often progress without meeting the minimum requirements regarding the necessary skills to perform in Mathematics tasks. In a local study on mobile, handheld games as Mathematics learning material, Roberts and Vänskä (2011) also implicate teachers as the gate-keepers for excluding learners from learning Mathematics through technology. Faye, Hasan, Abdullah, Bakar and Ali (2012), assert that incorporating digital game-based learning (DGBL) as a supplementary activity in teaching and learning of multiplication facts not only provides learners with opportunities to engage in authentic learning, but also yields better retention of facts, thus promoting better automaticity.

1.2.3 Affect in Mathematics education

Affect in Mathematics education is a multi-dimensional construct that will be explored in Chapter 2 (sub-section 2.4). As orientation to the study, the focus remains on academic emotions with specific reference to the negative effect of Mathematics anxiety on learners' affective states.

1.2.3.1 Academic emotions

Yan and Guoliang (2007) explains that the difference between academic emotions and achievement emotions lies in that *academic emotions* refers to learners' *achievement emotions* as experienced in all contexts of learning. In this study, the learning context of mathematics and Mathematics suffice. As part of a different research team, Pekrun made significant contributions in 2011 by theorising '*The Control Value Theory of Achievement Emotions*' that states that anxiety (for example) is made up of uneasy and tense feelings (affective component), worries (cognitive component), impulses to escape from the situation (motivational component), as well as peripheral activation (physiological component) (Pekrun,

[2] Calculations that are done in a learner's head without the use of pencil and paper, calculators or other aids. Mental mathematics often uses mathematics facts that a learner has already committed to memory and thus underpin automatisation.

Goetz, Frenzel, Barchfeld & Perry, 2011). In the current study anxiety experiences surrounding the process of automatisation of multiplication facts in different learning environments are studied. It therefore follows that the anxieties (if any) encountered will display some commonalities with what literature points to as '*Mathematics anxiety'*.

1.2.3.2 Mathematics anxiety

A characterisation

Research findings on Mathematics anxiety (MA) unravels this construct as negative emotional, mental as well as physical responses strongly associated with negative beliefs and attitudes towards Mathematics. Characterised by avoidance of situations involving Mathematics in a variety of situations (academic as well as ordinary life situations) and always accompanied by feelings of stress, anxiety and even dread are commonly referred to in literature *(*Arem, 2010; Ashcraft & Moore, 2009; Ashcraft & Ridley, 2005). Furthermore, somatic symptoms (kinesics) associated with Mathematics anxiety revealed that the symptoms are similar to that of general anxiety. Dowker, Bennet and Smith (2012), and Vukovic, Kieffer, Bailey and Harari (2013) explain that these symptoms may manifest as rapid pulse rate, nervous stomach, heart palpitations, tension headaches, visibly upset feelings expressed through sudden changes in behaviour and/or sweaty palms. Berch and Mazzocco's (2007) model focuses on various developmental, etiological and educational factors and also advance a negative feedback loop resulting from Mathematics anxiety. A Mathematics anxiety model postulated by Cavanagh and Sparrow (2011) highlights attitudinal, cognitive as well as somatic indicators related to Mathematics anxiety. In addition, Wang et al. (2014) found that genetic factors may contribute approximately 40 percent to manifestation of Mathematics anxiety. These genetic factors include both familial anxiety and familial difficulties in mathematical cognition.

Apart from the cognitive and affective factors that influence Mathematics anxiety, Wigfield and Meece (1988) also revealed academic as well as sociological factors. These factors can further be classified into: personal (age, gender and class); environmental (stereotypes, parent negative attitudes towards Mathematics); dispositional (confidence, attitude and self-esteem) and situational (classroom factors, instructional format and curricular factors) components (Ma, 1999).

Mathematics anxiety in middle childhood (5-9 years)

Studies on the role of affect in Mathematics education mainly involve pre-adolescents to adults. While it could be confirmed that Mathematics anxiety does indeed influence Mathematics performance, it does not necessarily follow that Mathematics anxiety in middle childhood will display similar characteristics to that of older learners and adults (Ashcraft, 2002).

There is, however, a growing body of scholarship confirming the roots of mathematics anxiety in middle childhood. This argument is consistent with the study findings of, Krinzinger, Kaufmann and Willmes (2009) that focussed on addition and subtraction operations in their measurement of Mathematics performance. These authors could, nevertheless, not find any significant correlation between Mathematics anxiety and performance. Studies that, however, incorporated the four basic operations such as that of Vukovic et al. (2013) and Jansen et al. (2013) equally stated a correlation between emotional experience of Mathematics and actual performance in Mathematics. In contrast to studies involving older learners, the nature of the Mathematics anxiety rating scale as well as the nature of mathematical problem solving tasks could have a detrimental effect on research outcomes (Wigfield, Eccles, Covington & Dray, 2002).

Alleviation of Mathematics anxiety

A general lack of evidence regarding the outcomes of the suggested alleviation of Mathematics anxiety still prevails. No longitudinal studies could be found during this review. Those that are identified suggest intervention programmes should consist of psychological treatments (for example cognitive behaviour therapy) and classroom interventions, such as structured Mathematics courses, corrective feedback, accommodation of various learning styles, positive psychosocial classroom atmosphere, modelling problem solving, instructional games and CAI (Wei, 2010). Researchers are, however, in agreement that intervention should commence during early school years and that it should address both affective as well as cognitive aspects of Mathematics anxiety (Vukovic et al., 2013).

Mathematics anxiety rating scales

Rating scales were developed to pursue empirical findings of Mathematics anxiety in relation to other variables – mostly performance in Mathematics. (Wigfield et al., 2002) comment on the use of rating scales for younger learners by arguing that these learners may experience difficulty in making realistic assessments of their own performances and that the learners may be inclined to rate themselves too high at such an age (Lehner, 2008). Gierl and Bisanz (1995) criticise the tendency to only use quantitative measures and suggest that more converging evidence will be obtained when qualitative studies based on behavioural observations are also conducted. As far as could be established, a lack of qualitative studies or studies applying multi-methods was conducted to investigate Mathematics anxiety during middle childhood years. This review of existing literature will therefore focus on the use of computer-assisted instruction through learner support and technology in Mathematics education.

1.2.4 Computer-assisted instruction (CAI) in Mathematics education

Research on whether the use of computers affects academic performance did produce varied conclusions. Some research indicates enhancement, while others conclude that computers are of questionable effectiveness (Gee, 2007). This difference could be explained by the fact that CAI is composed of two dominating digital environments and that affective experiences, such as Mathematics anxiety, can be experienced differently within these two environments (Mcquiggan, Lee, & Lester, 2007). In, a) computerised drill-and-practice (CDP) learning environments, gaming success is associated with the maximum number of correct multiplication facts provided in the minimum amount of time, while in b) digital game-based learning (DGBL) environments the aim is to solve more and more complex problem situations by means of providing correct multiplication facts. Gaming success in DGBL games is associated with moving to more complex game stages and the multiplication skills are only considered as tools in unlocking these stages and does not represent the ultimate goal of the game (Gee, 2007).

1.2.4.1 Computerised Drill-and-Practice (CDP) gaming environments

Duhon, House and Stinnett (2012) and Lehner (2008) agree that within CDP environments, multiplication facts may lead to improved performance, which in turn, will reduce Mathematics anxiety (Ashcraft & Ridley, 2005). Bochniak (2014) concludes his review of literature by stating that CAI proves to be most effective when it incorporates drill and practice, and when it is used at primary school level. Since limited research was found on the effectiveness of CDP environments, it cannot be concluded CDP environments do indeed promote the automatisation of multiplication facts as concluded by Bochniak (2014). Neither could it be ascertained that CDP environments could be associated with Mathematics anxiety (Squire & Jenkins, 2003, cited in Ke, 2008).

1.2.4.2 Digital game-based learning (DGBL) gaming environments

In discussing DGBL, the cognitive gains that it is said to produce (as well as which game type would result in these assumed cognitive gains) remains a controversial issue (Vogel et al*.,* 2006). On the one hand it is argued that digital games are suited to facilitate learning by improving problem solving skills (Bottino, Ferlino, Ott & Tavella, 2007), enhance classroom instruction (Blamire, 2009) and differentiate learning (Ke, 2009). On the other hand, sceptics maintain that game-based learning does not appeal to all learners although it may foster higher-order thinking skills (Ke, 2009). Schaaf (2012) adds to this by emphasising that the learning goal should always incorporate the element of play so as to keep learners optimally engaged throughout the lesson. The choice of games is therefore crucial. In their meta-analysis, McClarty Orr, Frey, Dolan, Vassileva and McVay (2012), conclude that DGBL can generally be proclaimed effective, but suggest that researchers should turn away from the governing *'if'* controversy that dominated research for more than two decades and instead turn face towards 'how*'* DGBL can facilitate and support learning through building confidence.

1.2.5 The role of computer- assisted instruction (CAI) on affect in Mathematics education

Since the turn of the century researchers began to confirm that CAI could result in learners' heightened enthusiasm about, and engagement with Mathematics tasks and by doing so, promote reduced Mathematics anxiety (Nordin et al*.,* 2013). With this knowledge, motivating and engaging learner friendly CAI environments brings into question the use of CAI as a tool to alleviate Mathematics anxiety (MA) and foster performance in Mathematics tasks. Even so, researchers seem to have considered similar gaming environments before the turn of the century – at times when digital games were still in their inception phase. For instance, Harris and Harris (1987) already established that CAI environments could possibly reduce MA. These speculations prevailed during the following two decades. In 2009, however, new perspectives were shared as Sun and Pyzdrowski (2009) focussed on technology (CAI) as a tool to reduce MA. They attributed the effectiveness of CAI to the promotion of learner engagement and learner centred activities, with a range of tasks and challenges with instant feedback in developmentally appropriate learning environments. Although research has concluded that the use of the appropriate CAI may support learners with mathematics anxiety (Fengfeng, 2009), the characteristics of both CDP and DGBL environments and its effect on learners' MA when teaching and learning multiplication facts remains largely unknown. From the limited empirical evidence, many inconclusive findings as well as a general lack of research regarding the impact of CAI on affect in Mathematics education in the middle childhood years still exists.

Within the context of learning support, the researcher had been (and still is) in the position of witnessing self-confidence boosts that technology (especially hand-held devices such as tablets, i-pads and even cell phones) creates in learners moving from the third to fourth grade (Grades 3 to 4): Learners who already displayed vulnerabilities regarding Mathematics in Grade 3 are frequently overwhelmed by the pace of teaching and learning of Mathematics in Grade 4 – resulting in more backlog regarding fundamental skills (for example the automatisation of multiplication tables). Being able to attend to the same skill (although at a lower level) through CAI, can break the negative feedback cycle that is created when a struggling learner is expected to perform at grade level in class without the lower level skills 'gaps' being filled upfront through remedial tuition. Having experienced success at lower skill levels, boosts the learner's confidence to attempt engaging at higher levels – changing disheartened learners who often refuse to participate into confident learners realising that they are able to overcome the barriers that kept them back.

1.3 Lacunae in Literature

Leder and Forgasz (2006) as well as Li and Ma (2010) pointed out a lack of evidence regarding the impact of CAI in the affective domain of Mathematics. Krinzinger et al. (2009) assert that measuring outcomes for only addition and subtraction computations might not be the most effective measure in investigating the relationship between Mathematics anxiety and performance in Mathematics. In multiplication skills, learners need to retrieve stored information from the long term memory, but often the skill has not been stored appropriately and retrieval becomes difficult, sometimes even impossible (Krinzinger et al., 2009). These authors also urge researchers to observe physiological reactions that could be associated with Mathematics anxiety as well as avoidance behaviours in young learners as it could be more reliable and valid than quantitative data obtained from MA rating scales.

It seems that a scarcity exists in the literature regarding MA in young learners and the use of CAI environments within the teaching and learning of multiplication facts (Eden, Heine & Jacobs, 2013). Some of the suggested areas of paucity include a need for research on the antecedents of MA (Ashcraft & Moore, 2012), the prevalence and manifestation of MA in young learners as studies with older learners divert attention from early identification and alleviation of MA (Wu et al., 2012). There seems to be a lack of research investigating the Mathematics anxiety experiences of Grade 4 learners (9-11year old age group) while automaticity of multiplication facts within both CDP and DGBL environments are pursued. Although research have concluded that the use of appropriate CAI can support learners with mathematics anxiety (Ke, 2009), the anxiety experiences in both CDP and DGBL environments during automatisation of multiplication facts remain largely unknown.

1.4 Databases, Research-Engines and Key constructs

An internet study was launched to obtain relevant scholarly work. The following search engines and databases were consulted: Questia online research library, EBSCOHost, ACM digital library, ERIC database, PsychINFO, ProQuest, JSTOR as well as Nexus Database System. Keywords and phrases used to launce these searches were (amongst others): math* anxiety; affect in Math* education; academic emotions; anxiety↔confidence valence; affective computing; computer-assisted instruction; technology in math* education; computerised drill and practice; game-based learning; digital game-based learning; educational computer games; video games; computational fluency and automaticity.

As key constructs of the study, the following concepts emerged: *anxiety↔confidence* valence; Mathematics anxiety; academic emotions; automaticity regarding multiplication facts; computational fluency, computerised drill and practice (CDP) learning environments; conventional teaching and learning environments; digital game-based learning (DGBL) environments and computer-assisted instruction (CAI). The aforementioned constructs are defined in context when each specific construct is introduced in the text for the first time. (Hyperlinks to the chapter and sub-section are enabled).

Table 1.1. *Key constructs of the study defined*

Key constructs	Definitions: Chapter and section/sub-section reference
Academic emotions	Chapter 1, sub-section 1.2.1
Anxiety ↔ confidence valence	Chapter 1, sub-section 1.1
Mathematics anxiety	Chapter 2, sub-section 2.4.3
Flow	Chapter 2, sub-section 2.3.4.2
Automaticity *(in the context of multiplication facts)*	Chapter 2, sub-section 2.2.2
Computational fluency	Chapter 2, sub-section 2.2.1
Mental mathematics	Chapter 2, sub-section 2.2.4.1
Computer-assisted instruction (CAI)	Chapter 2, sub-section 2.5
Computer drill and practice (CDP) learning environment	Chapter 2, sub-section 2.5.1
Digital game-based learning (DGBL) environments	Chapter 2, sub-section 2.5.2
Conventional teaching and learning environments	Chapter 1 sub-section 1.6
Rote memorisation	Chapter 1, sub-section 1.2.2

1.5 Research Questions

The study will be steered by the following research question:

1.5.1 Main research question

To what extent do Grade 4 learners experience anxiety in computer-assisted instructional environments during automatisation of multiplication facts?

1.5.2 Research sub-questions

- Research sub-question 1: What is the conceptual value of adapting the SEMA instrument with regard to the research design of the study?
- Research sub-question 2: What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?

- Research sub-question 3: Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?
- Research sub-question 4: To what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts?
- Research sub-question 5: To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?
- Research sub-question 6: To what extent, if any, do Grade 4 learners experience anxiety in DGBL learning environments during the automatisation of multiplication facts?

1.6 Purpose of the Study

In line with the research questions, the main purpose of this study is to interpret (thereby to describe, identify and understand) Grade 4 learners' *anxiety↔confidence* experiences during automatisation of multiplication facts across different learning environments (CAI and conventional classroom as well as home learning environments). Conventional learning environments refer to learning and teaching in classrooms without CAI and the informal learning and teaching taking place in learners' primary educational environment – often referred to as within the home and/or family. Conventional learning environments are relevant to this study as leaners' Mathematics anxiety experiences in CAI environments can only be understood when compared and contrasted to Mathematics anxiety experiences in conventional learning environments (Zan, Brown, Evans & Hannula, 2006). Due to this purpose, a series of sub-purposes are proposed across the different research phases.

With reference to research sub-question 1: To describe the conceptual value of adapting the SEMA instrument with regard to the research design of the study.

With reference to research sub-question 2: To identify the game design criteria that would possibly foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional (CAI) environments.

With reference to research sub-question 3: To identify suitable computer games, for fostering automatisation of multiplication facts in a CDP and a DGBL environment, that adhere to as many game design criteria as identified through answering the previous research sub-question?

With reference to research sub-question 4: To understand to what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts.

With reference to research sub-question 5: To understand to what extent, if any, do Grade 4 learners experience anxiety in CDP environments during the automatisation of multiplication facts.

With reference to research sub-question 6: To understand to what extent, if any, do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts.

1.7 Research Design and Methodology

A narrative account of the proposed research design and methodology will now be discussed.

1.7.1 Qualitative approach

The researcher proposes to put forward a multi-method qualitative approach to interpret the experiences of Grade 4 learners' *anxiety↔confidence* experiences across different learning environments while automatising multiplication facts in a sub-urban primary school setting. A multi-method qualitative research approach will be maintained throughout while integrating a series of research designs across two phases (Phase 1 and Phase 2). The first phase of the study is divided into Phase 1A and Phase 1B to distinguish between research sub-questions 1, 2 and 3. Phase 1A follows a content analysis design whereas Phase 1B follows a qualitative survey design. The second research phase (consisting of Phase 2A and 2B) leans towards a case study design to understand the research problem in a sub-urban South African primary school.

Phase 1A and 1B respectively prepare research tools to be used during Phase 2. Phase 1 can be viewed as the preparation phase. As the data to be analysed in Phase 2 are collected in two different learning environments as well (conventional and CAI), the case study research design will subsequently refer to Phases 2A and 2B respectively.

Conducted from an interpretivist perspective the study strives towards an understanding of how participants (learners) experience *anxiety↔confidence* in situations where they have to learn multiplication facts using a series of different CAI strategies as compared to conventional teaching and learning strategies possibly encountered at home and in classroom. Tables 1.2 and 1.3 provide an overview of the research design.

Table 1.2. *Overview of research design: Phase 1*

RESEARCH PHASE	Research sub-questions	Purpose (preparing two research tools to be used during Phase 2)	Methods of data collection	Analysis procedures	Sample and sampling strategies	Chapter in which findings are revealed
PHASE 1A (Pilot project)	Research sub-question 1: *What is the conceptual value of adapting the SEMA instrument with regard to the research design of the study?*	Preparing for Phase 2 by describing the conceptual value of adapting the SEMA instrument with regard to the research design of the study.	Adaptation of the SEMA instrument and pilot project.	Content analysis of SEMA to contextualise to South African context.		
		Focus group interview questions and open-ended prompts were compiled to be used in the South African context by adapting the SEMA instrument developed by Wu et al. (2012)	Re-adaptation of SEMA instrument according to data collected through observing the research respondents taking part in the pilot project.	Content Analysis of the pilot project: respondents' responses to trialled questionnaire items were analysed to produce a final draft of the adapted SEMA instrument.	Six grade 4 learners sampled by means of criterion sampling	6
PHASE 1B	Research sub-question 2: *What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?*	Preparing for Phase 2 by identifying the game design criteria that would possibly foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional (CAI) environments.	Literature review on CAI game design criteria	Content analysis: tabulation of game design criteria to align with design criteria of traditional (classroom) learning environments	Relevant literature on CAI games available to the researcher at the point in time were sourced through convenient purposive sampling.	
	Research sub-question 3: *Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?*	Preparing for Phase 2 by identifying suitable computer games, for fostering automatisation of multiplication facts in a CDP and a DGBL environment, These games need to optimally adhere to the game design criteria as identified through answering the previous research sub-question.	Qualitative survey by means of open ended teacher and learner questionnaires.	Qualitative analysis (categorisation and interpretation of common themes through a-priori coding)	Game samples by which teacher and learner respondents completed qualitative survey questionnaires. The sampling was done by means of convenient and purposive measures. Teacher and learner samples: 25 teachers and 24 learners were sampled by means of convenient, purposive measures.	6

Table 1.3. *Overview of research design: Phase 2*

RESEARCH PHASE	Research sub-questions	Purpose	Methods of data collection	Analysis procedures	Sample and sampling strategies	Chapter in which findings are revealed
PHASE 2A	Research sub-question 4: *To what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home instructional environments during the automatisation of multiplication facts?*	To understand how Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts.	Focus group interview Data type: verbal (*verbatim* transcriptions of audio recordings) Used final draft of adapted SEMA instrument as interview statements and open-ended questions to a qualitative sample (six Grade 4 learners)	Case Study: Inductive reasoning: categorisation and interpretation in terms of identified common themes (Atlas.ti)	A qualitative sample of six grade 4 learners were invited as research participants by means of criterion sampling. These participants were sampled form a population of all the grade 4 learners at the research site.	7
PHASE 2B	Research sub-question 5: *To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?* Research sub-question 6*: To what extent, if any, do Grade 4 learners experience anxiety in DGBL learning environments during the automatisation of multiplication facts?*	To understand how Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts. To understand Grade 4 learners experience anxiety in DGBL learning environments during the automatisation of multiplication facts.	Video-recorded gameplay sessions Data type: non-verbal (audio and visual). Three individual gameplay sessions with respective participants. Three different games aiming at automatisation of multiplication facts were used. Individual post-gaming reflections Data type: verbal (*verbatim* transcriptions of audio recordings) Interview questions to elicit individual self-reflective responses on gameplay experiences.	Case Study: Inductive reasoning: categorisation and interpretation in terms of common themes (Atlas.ti)	The six focus group interview participants were reduced to four to take part in the gameplay sessions, and the subsequent individual post gameplay individual interviews by means of a criterion sampling procedure.	8

Although the tabulated information follows in linear order, it needs to be taken into account that Phases 1A and 1B took place concurrently while Phase 2 only commenced after the completion of the research procedures of both preparatory phases, Phases 1A and 1B. It was not only convenient, but also practical to commence both Phases 1A and 1B at the same time. The literature review (phase 1B) and the adaptation draft of the SEMA instrument could commence while ethical clearance was awaited before the focus group interviews and distribution of teacher and learner questionnaires could be distributed. Phases 2A and 2B are, however sequential processes as the gameplay sessions had to take place between the focus group interview and the post-gameplay individual interviews. Tables 1.2 and 1.3 orientate the reader towards the research sub-questions pertaining to each phase, the purpose of the research procedures, the data types and methods of data collection, the analysis methods and tools, the sample and sampling strategies as well as the chapters containing the analysis findings. The next two chapter sub-sections will briefly outline the data collection procedures, the data analysis and the population and sampling processes.

1.7.2 Data collection and analysis procedures

1.7.2.1 Orientation to the data collection and analysis procedures and research contributors

Phase 1 can be viewed as the preparatory research phase – "producing" the research instruments. Phase 1A: open-ended SEMA questions to be used as interview questions in the focus group interview (that took place during Phase 2A) and Phase 1B: appropriate CAI games whereby the gameplay sessions of Phase 2B took place. The specific research processes will be outline in sub-sections 1.7.2.2 to 1.7.2.4.

In qualitative studies, research 'participant' is generally the accepted term when referring to research contributors. The researcher, however, wishes to agree with Jansen (2010), Roller (2014, 2015) in viewing the survey contributors in qualitative studies as 'respondents' and not as participants. As both types of research contributors are used in this study, the term 'respondents' is used to describe the contributors to surveys (pilot project respondents, teachers and learners who completed questionnaires) in the first research phase. The remaining research contributors (Phase 2) are referred to as 'participants' as they contributed by means of a focus group interview, gameplay sessions and individual interviews; generating more and deeper data to be analysed.

1.7.2.2 Data collection and analysis procedures: Phase 1A

The content analysis of the original SEMA instrument (Scale for Early Mathematics Anxiety) of Wu et al., (2012) that took place during Phase 1A, enabled adaptation of the instrument as it had originally been designed to measure Mathematics anxiety quantitatively and not qualitatively as in the current study. After trialling this first draft by means of a pilot project, the SEMA instrument had to undergo further adaptation as it had been designed for learners outside the South African cultural and Mathematics curriculum context. The SEMA instrument also aimed at a younger chronological age group as that of the current study. The respondents' responses to trialled questionnaire items were analysed by means of content analysis to produce a final draft of the adapted SEMA instrument.

1.7.2.3 Data collection and analysis procedures: Phase 1B

Phase 1B (that took place concurrent with Phase 1A) could be considered as preparation phase for Phase 2 as the game design criteria that would possibly foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional (CAI) environments were identified. A literature review and content analysis of all literature available to the researcher was undertaken to enable tabulation of the game design criteria that would align with design criteria of traditional (classroom) learning environments. These design criteria assisted in drafting qualitative open-ended survey questionnaires that were completed by teacher and learner respondents.

By analysing the qualitative survey data, appropriate games in both CDP and DGBL environments were selected for the gameplay sessions in Phase 2 of the study.

1.7.2.4 Data collection and analysis procedures: Phases 2A and 2B

The research design of the second research phase follows that of a case study design. The aim of the research activities during Phase 2A was to understand how Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts. As these activities only set the scene for answering to the main research question and not answering to it directly, the use of a focus group interview with learners as participants was preferred over and above that of individual interviews. The individual gameplay sessions and individual reflections obtained through post-gameplay interviews (Phase 2B) were considered to yield ample individual responses. Furthermore: as the focus group interview statements and open-ended questions were trialled during the pilot project, the researcher (as interviewer) was prepared in managing the interview in such a way that participants could freely share their views and not be intimidated or inhibited by fellow participants (Please refer to audio recordings and transcriptions of the focus group interview).

The aim of the research activities of Phase 2B was similar to that of Phase 2A: Participants' anxiety experiences while automatising multiplication facts were observed in order to be better understood. In contrast to Phase 2A, the participants' output was non-verbal. The participants' non-verbal expressions while playing CAI games aimed at automatising multiplication tables, were observed and analysed through examining the video-taped recordings of the gameplay sessions and the field (observational) notes captured by the researcher as inside observer during gameplay sessions. To enrich this data, participants were interviewed during individual post-gameplay, semi-structured interviews on their gameplay experiences (verbal data).

The data collected in Phases 2A and 2B were analysed by means of inductive reasoning: categorisation of the data and constant comparison to reveal findings about the participants' *anxiety↔confidence* experiences in class and home environments as well as CAI learning environments (CDP and DGBL domains respectively).

1.7.3 Population and sampling

Population and sampling**:** In this study, literature, CAI- games and research contributors had to be sampled. The sampling took place in stages across both research phases.

1.7.3.1 Population and sampling: Phases 1A and 2A

Twelve grade 4 learners were sampled by means of criterion sampling from a population of all the grade 4 learners at the research site as research contributors following Maree's (2007) definition of criterion sampling as it is, in the researcher's opinion, a more controlled sampling method than the usual purposive sampling applied in qualitative research. Six learners were invited as research respondents in Phase 1A's pilot project and the remaining six were invited to participate in the focus group interview of Phase 2A. Identical sampling criteria for respondents (pilot project) and participants (focus group interview) were applied. This is due to the fact that during Phase 1A's pilot project the researcher trialled, and afterwards refined a research tool (interview statements with added open-ended prompts) for use during the focus group interview that took place during Phase 2. A detailed description of, and the rationale for the criteria applied to sample two homogenous groups that could yield similar information on the phenomenon under discussion (anxiety experiences while automatising multiplication facts), are provided in Chapter 4, sub-section 4.3.2. Stating the three selection criteria will serve to orientate the reader at this point. Research contributors had to a) be of the same gender, b) display close proximity in terms of date of birth, and c) display equal language proficiency in the English language.

1.7.3.2 Population and sampling: Phase 1B

Firstly, the relevant literature on CAI games was sourced (through convenient purposive sampling) for reviewing in order to identify the underlying game design criteria of CAI games in both the CDP and DGBL domains. These results led to another (second) stage of sampling where appropriate CAI games (once again in both CDP and DGBL domains) were sourced.

These games served as the games sample (n=6) by which teacher and learner respondents completed qualitative survey questionnaires. The sampling was, once again, done by means of convenient and purposive measures. To find teacher and learner respondents for this qualitative survey, 25 teachers and 24 learners were sampled by means of convenient, purposive measures.

1.7.3.3 Population and sampling: Phase 2B

The last stage of sampling took place when the six focus group interview participants were reduced to four to take part in the gameplay sessions, and the subsequent individual post gameplay individual interviews of Phase 2. A single criterion, namely the extent of prior gameplay experience, as reflected on by participants' parents/caregivers, was applied during the sampling process.

1.8 Context of the Research Site

With the exception of teacher questionnaires which were distributed to Mathematics and/or Computer teacher respondents from neighbouring schools, data was collected at a single research site. This site is a suburban, parallel medium, ordinary public primary school, situated in the Tshwane South education district of the Gauteng Department of Education. The term 'ordinary school' needs to be understood as one of the three schooling provisons of the South African public school system: **ordinary** public schools, public schools for learners with special education needs or public schools that provide education with a specialised focus on talent, including sport, performing arts or creative arts (South African School's Act, 1996). When data was collected in 2014, the school had approximately 1320 learners of which approximately 300 were taught in Afrikaans while the rest had English as medium of learning and teaching.

1.9 Paradigmatic Supposition of the Researcher

The researcher can affirm that all individuals have their own unique interpretation of reality and that a single reality does not exist. This pragmatic ontology does not negate the objective truths underlying the positivist approaches but favours an interpretive and constructivist view whereby individuals create meaning within their natural settings.

1.10 The Role of the Researcher and Research Contributors (respondents and participants)

In a qualitative study, the researcher is the instrument facilitating the data (Leedy & Ormrod, 2010). The researcher therefore took on the role of an objective inside observer during the gameplay sessions, pilot project, focus group interview and post-gameplay individual interviews. In addition to and apart from above-mentioned researcher's roles, the researcher was also responsible for developing research instruments (adapted SEMA instrument, teacher and learner qualitative survey questionnaires), the researcher also compiled field notes clarifying participants' informal reactions and reflections during the gameplay sessions (Phase 2B) where the mode of output was non-verbal. The researcher's role was carried out in the context of, and within the research site as discussed in a previous sub-section (sub-section 1.8)

The roles of the research contributors were diverse; it ranged from responding to a statement by means of pointing to a picture on an artefact, to communicating *anxiety↔confidence* experiences verbally and non-verbally, to responding to distributed questionnaires as part of a qualitative survey. These roles will be described in detail in Chapter 4, sub-sections 4.4 and 4.7 as well as Chapter 5, sub-sections 5.5 and 5.6.

1.11 Rigour

1.11.1 Trustworthiness

Unlike quantitative studies that seek to examine measurable, objective data and causal relationships between variables, qualitative research involves processes and meanings that cannot always be investigated experimentally. Denzin and Lincoln (2011) stress the fact that it is the essential qualities of qualitative investigations namely socially constructed realities and relationship between the researcher and these socially constructed realities that make the research prone to researcher bias.

Trustworthiness is, however, the means whereby the plausibility, credibility and integrity required for ensuring the scientific merit of qualitative research studies, are demonstrated. The most widely used criteria for evaluating qualitative content analysis are those developed by Lincoln and Guba (1985) who claim that aim of trustworthiness is to validate that the qualitative research findings are worth paying attention to. In agreement, Carnine (1995) refers to trustworthiness as the confidence with which the findings can be acted upon by practitioners. The most common criteria used to evaluate the trustworthiness of qualitative research studies are *credibility, dependability, transferability* and *confirmability* (Lincoln & Guba, 1985).

Credibility refers to the extent to which the researcher is able to accurately represent the multi-dimensional nature of the researched, socially constructed realities. In the current study the complex nature of the process of grade 4 learners acquiring automaticity in multiplication tables through CAI had been under scrutiny. To enhance the *credibility* of the study prolonged, intense engagement with the research participants and persistent observation of the phenomenon under various natural situations were maintained. This planned engagement took place in different contexts (a focus group interview, gameplay sessions and post-gameplay individual interviews) in aim to identify reoccurring patterns and possibly limiting participants' inclination to provide so-called socially desirable responses over and above personal experiences. Simultaneously, the researcher took ample precautions not to become enmeshed with the participants; not able to separate the researcher's own experience from that of the participants. This was done by keeping research contact professional, yet warm and inviting, but also limiting contact with participants outside research activities. As the researcher was inseperable from the data gathering process, frequent self-reflective activities were planned to prevent own characteristics from influencing the data gathering and ultimately the data analysis process. These reflections were kept as part of the researcher's field notes.

Krefting (1991) describes triangulation as a powerful source whereby the credibility of qualitative research can be measured. The way in which multiple perspectives revealed through analysis of different data sources converged in this study, is carefully described in chapter 4 (sub-section 4.9) and chapter 5 (sub-section 5.7). Data source and data collection triangulation, data analysis triangulation and methodological triangulation were outlined.

Peer review was also used to enhance credibility. As the interpretation of non-verbal modes of communication was central to the overall data analysis, the video-taped gameplay recordings were viewed by a colleague who recently completed similar post-graduate studies. This was done to prevent researcher bias when observing the non-verbal communication.

To further enhance the credibility of the current study, the authority of the researcher as human research instrument can be inferred by understanding the researcher's degree of familiarity with the phenomenon and under study, the researcher's strong interest in conceptual knowledge, the ability to conceptualise large amounts of qualitative data, the researcher's ability to follow a multi-method approach and view the subject under investigation from different theoretical perspectives. The researcher furthermore demonstrates good investigative skills that were developed through literature review, course work in educational psychology and two decades of learner support field work.

Dependability relates to the consistency of findings should the current study be replicated. According to Lincoln and Guba (1985) *dependability* is an integral component of trustworthiness and involves the researcher being able to give the reader ample information to determine how dependable the study and the researcher are. Through methodological triangulation described in chapter 4 (sub-section 4.9) and chapter 5 (sub-section 5.7) the level of dependability could be raised by ensuring that the weakness of one method of data collection and analysis are compensated by the use of alternative data-gathering and analysis methods. The principles and criteria used to select research contributors were also discussed in detail to enhance assessing the transferability of the results of the study to other contexts.

Transferability, also described as ‘fittingness’ by Lincoln and Guba (1985), refers to whether the study findings can be applied outside the context of the study. A study can therefore be declared to have met the criterion of transferability when the findings can match other contexts and readers can relate the findings to their own contexts and experiences. Transferability is also enhanced when the results are experienced as meaningful to stakeholders not involved in the current research study.

Confirmability is established when credibility, transferability and dependability are achieved and it refers to the aspect of objectivity - the potential for correspondence between two or more independent people about the accuracy, relevance and significance of the data and research findings (Lincoln & Guba,1985; Elo et al., 2014). Confirmability therefore requires the researcher to prove that the findings are only derived from the data and therefore accurate reporting on how all conclusions and interpretations have been reached, remains vital.

In this study the researcher aimed to document the research design in a thorough manner and provide detailed descriptions of all phases of the process (preparation, organisation, and reporting). In this way the likelihood of overall trustworthiness was increased.

1.11.2 Ethical Rigour

Ethical guidelines serve as standards against which the researcher should evaluate his/her own conduct and are therefore internalised in the personality of the researcher (Strydom, 2005). All decisions regarding this research therefore rested upon the researcher’s personal moral principles.

Permissions from the relevant authorities and institutions, Grade 4 learners as research contributors, as well as their parents/caregivers were obtained prior to the respective data collection processes. As the proposed research project was undertaken in a primary school in Gauteng, formal permission from the Human Resources Department at the Gauteng Department of Education (GDE) was obtained once ethical clearance was granted by the Ethics Committee of the Northwest University. Permission was also requested from the school principal as well as the school governing body at the research site.

Arrangements were made with the school (research site) on agreed timeslots that did not interfere with the daily routine of the school. Instead, suitable extra-mural gameplay sessions were negotiated with the school management and parents/caregivers. Anonymity of research participants was guaranteed, even when reflections on, for example, their non-verbal communications through facial expressions, were requested. Research contributors’ participation was always voluntary and they were allowed to withdraw at any time. The aim and procedures of the study was explained to all the role-players in the distributed information/consent letters (Appendices Fi and Fii).

The selection of a homogenous gender sample was not due to gender bias and e*ither* boys *or* girls could be identified. As research findings by Stuart (2000), Zan et al. (2006) and Kim and Chang (2010) did indicate gender differences in learners’ Mathematics anxiety experiences, a homogenous gender sample was set as one of the selection criteria when sampling research contributors for both Phases 1A and 2 of the study.

Outcomes of this study will be made available to learners through an age-appropriate verbal explanation of how gameplay could benefit or hinder their in-class responses, in terms of multiplication facts assessments (mental mathematics tests). Respondents' parents/caregivers will be provided with verbal feedback on the conclusions of this study. Written conclusions (concise and summative research reports) of this study will be provided to the GDE and the principal of the school at the research site.

1.12 Contribution of this Study

The aim of this study is solely to contribute towards building knowledge through understanding Grade 4 learners' anxiety experiences in automatizing multiplication facts through computer gameplay in both CDP and DGBL environments. These gameplay experiences need to be viewed as learning support activities supplementary to the usual in-class and at home teaching and learning support strategies. Should gaps in the literature study (outlined in Chapter 2, sub-section 2.6) be addressed, this will be regarded as a *bona fide* benefit.

1.13 Chapter Layout

Table 1.4 summarises the division of the chapters and a synopsis of the content of each chapter.

Table 1.4. *Chapter layout*

Chapter	Title	Synopsis of chapter content
Chapter 1	Orientation	• Outlining the problem statement, rationale and the purpose of the study. • Key constructs pertaining to the study • Holistic overview on the research design • The paradigmatic supposition of the researcher, • Ethical considerations
Chapter 2	Literature review	• Computational fluency, Theoretical and Conceptual frameworks, Affect in Mathematics education and Computer-assisted instruction
Chapter 3	Cognitive and affective design criteria of computer assisted learning environments	• Content analysis: identifying design criteria of CAI games • Emotional design • Learning principles: conventional classroom instruction versus computer-assisted Instruction

Chapter 4	The Qualitative Research Design: Phase 1
	
	Chapter 4(a): Phase 1A
	and
	Chapter 4(b): Phase 1B
		• Both chapter sections include the interpretivist
		  • Research sub-questions,
		  • The sampling process,
		  • The researcher's and research contributors' roles,
		  • The research instruments and the
		  • Methods of data collection and analysis.
		  • Triangulation
		  • Ethical considerations and challenges to the research design

Chapter 5	The Qualitative Research Design: Phase 2	• This chapter includes the interpretivist
		  • Research sub-questions,
		  • The sampling process,
		  • The researcher's and research contributors' roles,
		  • The research instruments and the
		  • Methods of data collection and analysis.
		  • Triangulation
		• Ethical considerations and challenges to the research design

Chapter 6	Presentation of the findings: first data analysis phase	• Presentation of the findings derived from research procedures conducted as described in Chapter 4(a) and (4(b)
Chapter 7	Presentation of the findings: second data analysis phase	• Presentation of the findings derived from research procedures conducted as described in Chapter 5.
Chapter 8	Summary, discussions and recommendations	• Summary of the qualitative research study, comments, discussions, conclusions and possible recommendations for future research

1.14 Schematic Overview of the Research Process

Where Chapters 4 and 5 provides detailed graphical representations of the research procedures of Phase 1A and 1B, as well as Phase 2, this chapter concludes by presenting Figure 1.1 which provides a holistic overview of the components of the qualitative research design across the two phases.

To place the study within the larger educational research context, Chapter 2 follows by rendering a review of available, relevant literature on the main constructs of the study that encompasses computational fluency, the theoretical and conceptual frameworks, the role of affect in Mathematics education and computer-assisted instruction.

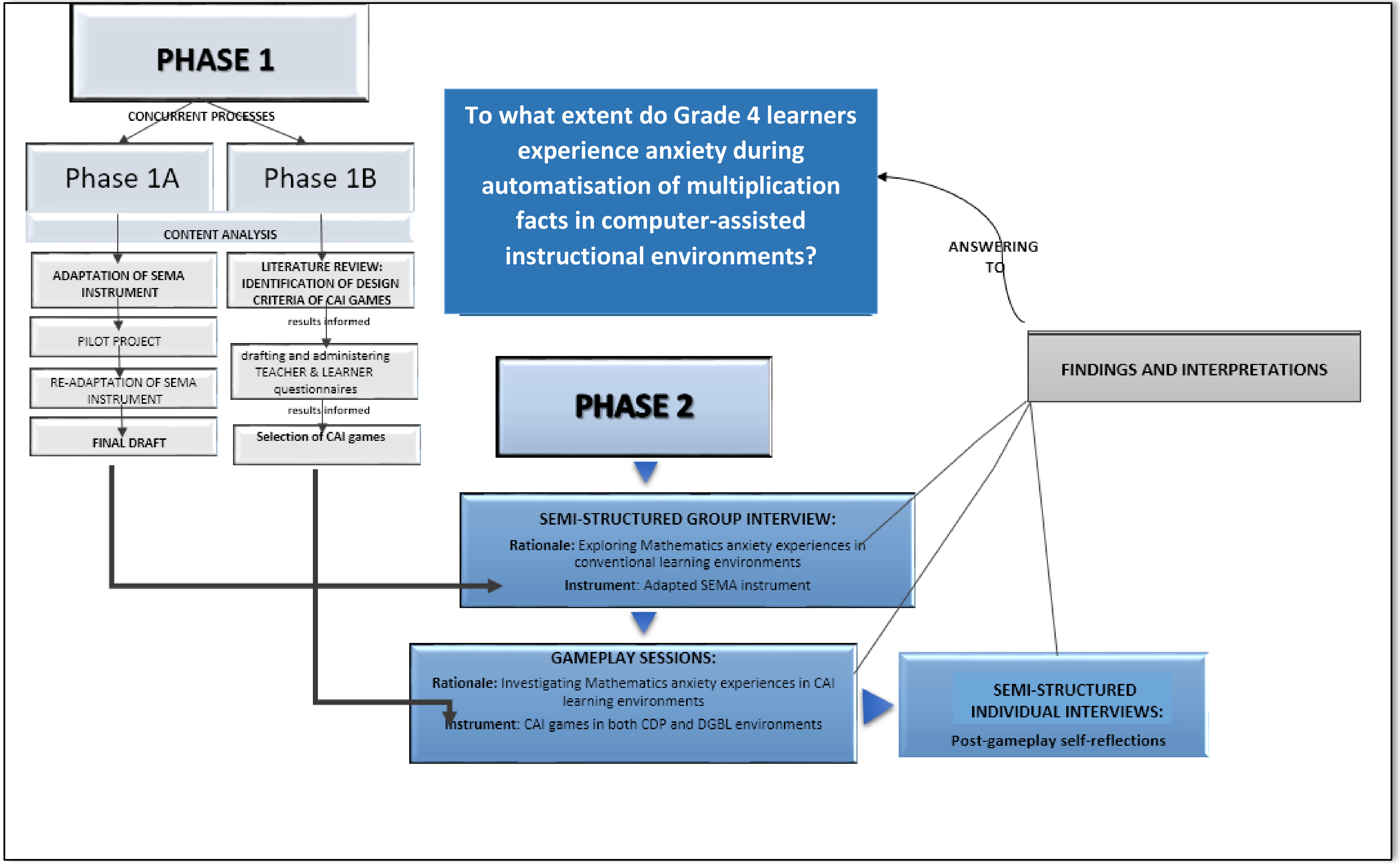

Figure 1.1. Holistic overview of the components of the qualitative research design across the two phases (Phases 1A and 1B, as well as Phase 2).

Chapter 2

Literature review: Computational fluency, Theoretical and Conceptual frameworks, Affect in Mathematics education and Computer-assisted instruction

"Mathematics education must take into account the induced changes through technological progress, as it cannot deny the existence of smartphones, tablets and computers."
(Vandebrouck, Monaghan & Lagrange, 2013, p.263)

2.1 Introduction

From the exposition of the research problem, a number of complex social realities, covering different disciplinary fields, arise. Cognitive and affective learner support in Mathematics and Computer-assisted Instruction (CAI) in Mathematics education seem to be the underlying issues within these social realities. Understanding if and how learners acquire knowledge and skills through gameplay, and whether or not they just seemingly play with such an immense motivational and emotional involvement, requires a theoretical perspective To provide a conceptual framework for the study, and place it within the larger educational research context, a review of relevant literature regarding computational fluency, relevant theoretical and conceptual frameworks, and the role of affect in Mathematics education as well as computer-assisted instruction (CAI) follows.

2.2 Computational Fluency

Conventional wisdom has it that basic computational fluency is a pre-requisite skill to facilitate higher-order processing in problem solving (Loveless, 2003; Smith, 2010; Westwood, 2003). Computational fluency implies the optimal development in the rapid recall or automatisation of computational facts. Developing this skill as early as possible is currently a concern in countries that are battling with recurring poor results of secondary school learners. In this regard, South Africa is no exception (DBE, 2012).

2.2.1 Defining computational fluency

Computational fluency refers to having efficient and accurate methods for computing. To be computationally fluent, a person needs to demonstrate *flexibility* in the computational methods they select. He/she furthermore needs to be able to *understand* and explain their methods, and produce accurate answers *efficiently* (Gojak, 2012). Kilpatrick, Swafford and Findell (2001) echo these findings by stating that attaining computational fluency- the efficient, appropriate, and flexible application of single-digit and multi-digit calculation skills - is an essential aspect of mathematical proficiency (Baroody, 2006). From these definitions it follows that a person cannot be computationally fluent without conceptual understanding and flexible thinking.

2.2.2 Automaticity

Automaticity refers to the computational fluency or efficiency acquired by means of the rote memorisation of computational facts without necessarily attending to conceptual understanding or strategic mathematical reasoning (Baroody, 2006). Martinez (2006), however, stresses that these automated processes complement cognition and need not be viewed as separate processes. Wong and Evans (2007), furthermore explain that without automaticity a learner's focus will remain on applying computational strategies rather than attending to the problem solving task at hand. Ironically, Boaler (2015) points to the fact that British Mathematics curriculum compilers currently ruled learners' automatisation of all times tables by the age of nine (after a British politician publically erred by calculating 7X8 as 54) while United States curriculum started to de-emphasise rote memorisation of multiplication facts. The manner in which computational fluency is developed therefore needs to be investigated.

2.2.3 Developing computational fluency

2.2.3.1 Time-drilled practice

Pegg, Graham and Bellert (2005) found that by improving the processing speed of basic computational skills, working memory capacity will be freed up to become available to address more difficult mathematical tasks. Understanding the functionality of a working memory clarifies the aforementioned statement: working memory is referred to as an information processing resource with limited capacity, simultaneously preserving information (for example computational facts) that are stored in long term memory for later retrieval as well as processing the same (for example memorising the computational facts) or other information (for example problem solving) (Martinez, 2006).

Research illustrates that the ability to recall information accurately and quickly uses minimal cognitive capacity (Ashcraft & Krause, 2007; Pegg et al., 2005) and therefore lacking automaticity can reduce a learner's ability to attend to higher order mathematical tasks such as problem solving. The characteristics of the working memory are commonly regarded as critical to investigations in barriers regarding computational fluency (Ashcraft & Krause, 2007; Cowan et al., 2011). However, both Lehner (2008) and Westwood (2003) caution us that where drilled practice may be essential for some learners, it could result in other learners losing confidence if they are not able to master *timed*-drill practice. Boaler (2015) supports this argument by stating that Mathematics facts are important but that rote memorisation by means of senselessly repeating times tables is damaging.

2.2.3.2 Strategy teaching

Advocates of strategy teaching (who place more emphasis on conceptual understanding and problem solving than on computational skills) still respect the importance of automaticity in basic mathematical facts (Woodward, 2006). Not only do they attribute barriers to fluency to difficulties regarding the *memorisation of* facts (Jordan, 2007) but they argue that strategies expand a learner's flexible use of numbers, and they therefore propagate strategy teaching for all learners at primary school level. Chinn et al. (2013) and Tipps and Johnson (2008) are also of the opinion that conceptual understanding and meaningful strategies in using the different operations (+,-, x and ÷) need to precede rote memorisation and drill-and-practice in acquiring computational fluency. Nevertheless, although strategy teaching inevitably promotes number concept, it does not necessarily lead to automaticity; frequent timed-drill practice is essential in becoming computationally fluent (Woodward, 2006).

2.2.4 Natural development

Baroody (2006) argues that learners are able to naturally develop strategies for learning mathematical facts when provided the opportunity. According to Jordan (2007) and Berch and Mazzocco (2007) some learners have an inborn aptitude and intuitive knowledge to working with numbers that will surface whenever in a conducive educational environment. The path to computational fluency is however less straight-forward for most learners and an integrated approach to acquiring computational fluency should be considered.

2.2.4.1 An integrated approach

Computational fluency cannot be anticipated if a learner has reached automaticity regarding number facts – automaticity and the development of *number sense* are intertwined and ought to be developed together, though not necessarily simultaneously (Bobis, 2007). Number sense can be defined as the capacity to be able to apprehend approximate numerosity, to discriminate between different numerosities, and to perform approximate calculations non-symbolically (Dehaene, Piazza, Pinel & Cohen, 2003). In 1935 Brownell and Chazal (as cited in Bobis, 2007) initiated an ongoing debate on the best approach to acquire computational fluency. Their work already questioned the traditional emphasis on rote memorisation, which can, in turn, reinforce a learner's use of immature methods for answering factual problems. Bobis (2007) confirmed this statement and disclaims that when learners are placed under some form of cognitive pressure, such as an imposed time limit, that they will often revert to a less sophisticated strategy which they know well, which seems easier and can perform with minimal effort at that point in time. These methods will not necessarily be accurate and will be time consuming. The inevitable sense of failure could result in desperation and feelings associated with mathematics anxiety. Baroody (2006) also argued that an approach based only on the timed-drill practice of multiplication facts is likely to serve as a roadblock to mathematical proficiency and could lead to mathematics anxiety.

Teaching strategies involving meaningful inquiry-based techniques and purposeful strategy teaching followed by timed-drill practice, can result in computational fluency (Woodward, 2006) as it could enable learners to use basic multiplication facts efficiently (accurately and quickly), appropriately (thoughtfully in both familiar and unfamiliar situations) and flexibly (inventively in new situations) (Baroody, 2006). High levels of efficiency in computation, however, remain a goal of mathematics curricula worldwide: South Africa's national curriculum refers to mental mathematics as the process by which this is achieved (DoBE, 2011a). In terms of mental mathematics (multiplication) at Grade 4-level, curriculum requirements (DoBE, 2011a, p. 36 - 37) display an integrated approach:

The mental mathematics should systematically develop three aspects of learners' number knowledge:

- Number facts: times tables involving multiplication of whole numbers to at least 10x10
- Calculation techniques: doubling and halving, multiplying by 10 and 100, multiplying by multiples 10 and 100 and building up and breaking down numbers

- Number concept: Counting: count forwards and backwards in 2s, 3s, 5s, 10s, 25s, 50s, between 0 and at least 500; Counting: count forwards and backwards in 100s between 0 and at least 1 000

2.2.5 Technology as assistive device

When it comes to the topic of using technological devices (for example calculators) for basic computations, literature readily agrees that increased reliance on technology cannot substitute the value of automaticity in facilitating numeracy (Thompson, 2011). Wolfram (2013, p. 9 -15), however, recently introduced a revolutionary pedagogy whereby the use of computers to take over calculations as early as possible is propagated. In his opinion automaticity regarding all calculations should be provided by computers - enabling learners to move beyond hand-calculations more readily and attend to more complex problem solving – "real math"- as he calls it.

Zan, Brown, Evans and Hannula (2006) rightfully assert it is impossible to understand and interpret human actions (for example acquiring computation skills) without considering *affect*. Applied to educational research, an interpretivist paradigm enables the researcher to build rich local understandings of the experiences of learners in different educational contexts (Taylor & Medina, 2013). To theoretically ground *affect* within the framework underpinning the design of educational games is an aspect often neglected. In this regard O'Riley (2016) urge teachers to form part of the design process of DGBL games as they (teachers) are the professionals who can provide adequate feedback in terms of affective responses when learners are using DGBL to acquire computational skills.

2.3 Theoretical and Conceptual Framework from a Computer-assisted Instruction (CAI) Perspective

2.3.1 Introduction

Designing an educational computer game is not a mere multi-disciplinary team effort; it is a large scale cross-disciplinary endeavour. In designing games for instructional purposes (CAI), game designers, according to Sedano (2012), often tend to favour the technological perspective over and above equally important learning and affective perspectives. Sedano (2012) furthermore emphasises that tensions frequently arise as a result of game designers downplaying the importance of learning theories. Game designers, information technologists and education scientists need a universal theoretical framework – drawing from *all* relevant theories in the respective fields. When describing teaching and learning with technology (CAI) from theoretical perspectives, it is important to not only take a stance from educational and technological perspectives, but also from an affective stance (Barlett, Anderson & Swing, 2009; Hense & Mandl, 2012). Figure 2.1 therefore illustrates the three different theoretical lenses (*learning*, *affect* and *flow*) through which the research problem will be investigated as well as the different disciplinary fields mentioned in sub-section (2.1).

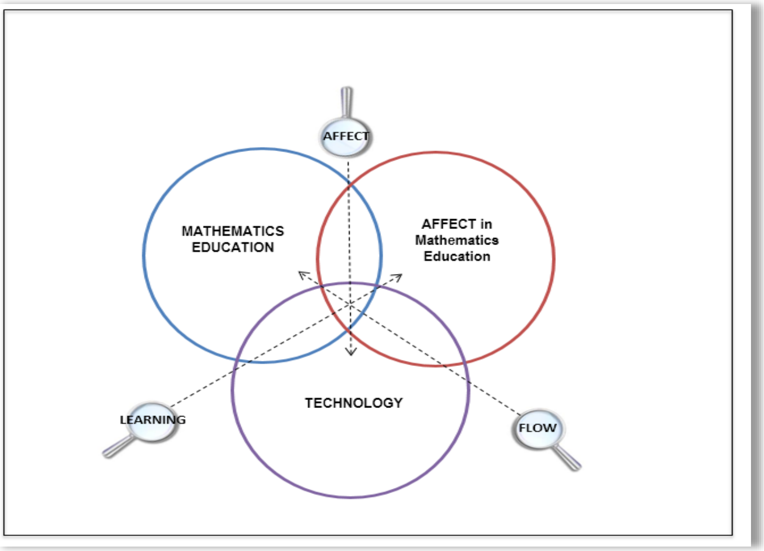

Figure 2.1. Disciplinary fields and theoretical lenses within the scope of the study

Figure 2.2 is an expansion of the previous figure (Figure 2.1) and illustrates not only the disciplinary fields (Technology- CAI, affect in Mathematics education and Mathematics education) but also the different theories and conceptual frameworks that served as frames of reference for this study.

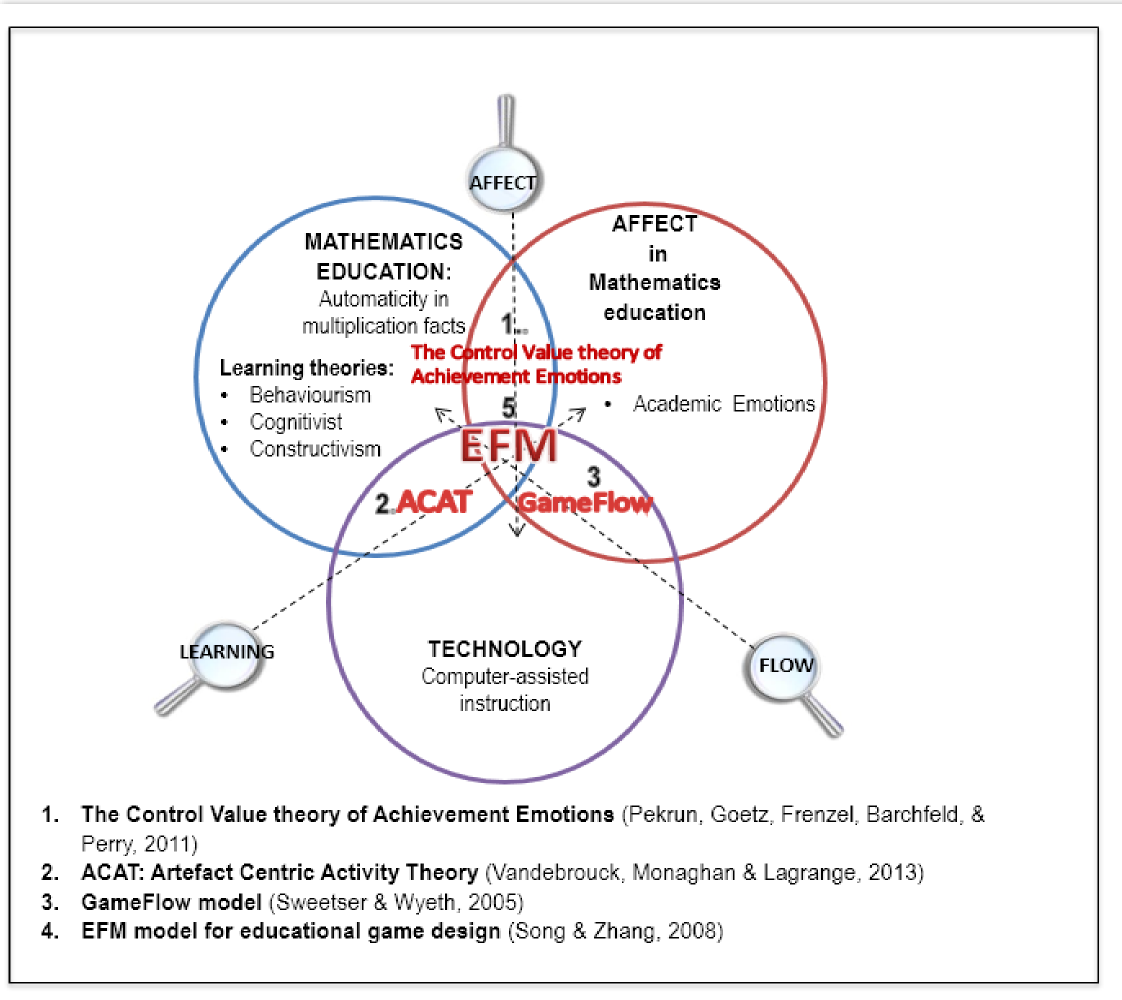

Figure 2.2. Theoretical and conceptual framework

As Activity theory (AT) supports the interpretivist paradigmatic supposition of the researcher, it will be utilised as the *learning lens,* by focussing on the Artefact - Centric Activity Theory (Vandebrouck, Monaghan & Lagrange, 2013). This theory draws from Activity theory and Constructionism[3] in the field of technology as well as from the aforementioned learning theories in the field of Mathematics education.

When the learning and teaching of Mathematics is described as an activity system, constructivism as a learning theory comes to mind. In viewing the use of computers as artefacts (means of mediating) other learning theories also come into play: Groff, Howells and Cranmer (2012), in search of a digital game-based pedagogy, explain that different learning theories become prominent in view of game designers' different perspectives on learning environments. In turn, it results in different genres of game design - each underpinned by a different theory of learning. These authors identify behaviourism, cognitivist theories as well as constructivism as relevant learning theories underpinning computer- assisted instruction (CAI).

The Control Value theory of Achievement Emotions serves as a theoretical bridge between the research fields of Mathematics and Affect in Mathematics education (Pekrun et al*.,* 2011). This theory affords an integrated approach for analysing different emotions experienced in achievement contexts. These achievement emotions are qualified as "sets of interrelated psychological processes, whereby affective, cognitive, motivational, and physiological components are of primary importance." (Pekrun et al., 2011, p. 37). Representing the *flow lens*, the interplay between motivational theories and design theories is culminated in the GameFlow model (Sweetser & Wyeth, 2005).

As an all-inclusive theory or model, that encompasses all previously exposed theories and models on game design (technology), motivation (psychology) as well as learning and teaching (Mathematics education), Song and Zhang's (2008) EFM model for educational design will be applied. In this model, E represents effective learning environments, F represents flow experiences and M refers to motivation. The different models and theories as exposed in Figure 2.2 will be discussed separately going forward.

2.3.2 Artefact-Centric Activity Theory (ACAT)

To understand abovementioned theory, basic knowledge of Activity theory is called for. Activity Theory describes activity as "any motivated and object-oriented human initiative, having its roots in cultural history, and depending for its actual occurrence on specific goal-oriented actions through the use of artefacts (tools)" (Jaworski & Potari, 2009, p.9). In this theory the *conscious* and *motivated activities directed at objec*ts (goals) become the focus of investigation. Cultural and technical mediators of human activity are, however, not studied in isolation, but are rather as part of the bigger system - a system of which the elements of activity are dynamically and constantly changing (Nardi, 1996; Engeström, 2000). Since LaCroix (2012) views computers as artefacts (mediating tools) and it is accepted that mathematics arise from cultural history (Bishop, 1988; Radford, 2008), choosing Artefact-Centric Activity Theory (ACAT) (Vandebrouck et al*.,* 2013) as the theoretical foundation for computer-assisted instruction in Mathematics, was relevant to the research problem. Within the parameters of this study, the *computer* will

[3] Not to be confused with Piaget's constructivism: Papert's constructionism, in contrast, focuses more on 'learning to learn', and on the significance of constructing things in learning. Papert stresses the importance of media, context and especially the use of artefacts (tools) in human development (Ackermann, 2001).

represent the technical mediator of human activity, and the *socio-cultural* as well as *historical context* of Mathematics education in South Africa will provide the background against which learners' anxiety experiences will be interpreted.

Vandebrouck et al. (2013) draws from Constructionism as a framework for exploring the construction of a learner's mathematical knowledge and skills – not from the learner's premises but from a design approach: designing digital artefacts in such a way that the manners in which learners manipulate the tool are conducive to generating meaning. The constructionist's approach to learning involves two activities: the construction of knowledge through experience and the creation of personally relevant products. The theory proposes that whatever the product, the design as well as implementation of the products should be perceived as meaningful to both the designer and those learning by using the artifact as a tool (Dondlinger, 2007). In this way, the ACAT for investigating teaching and learning in Mathematics by interacting with computers as virtual manipulatives in social settings (Figure 2.3) was founded.

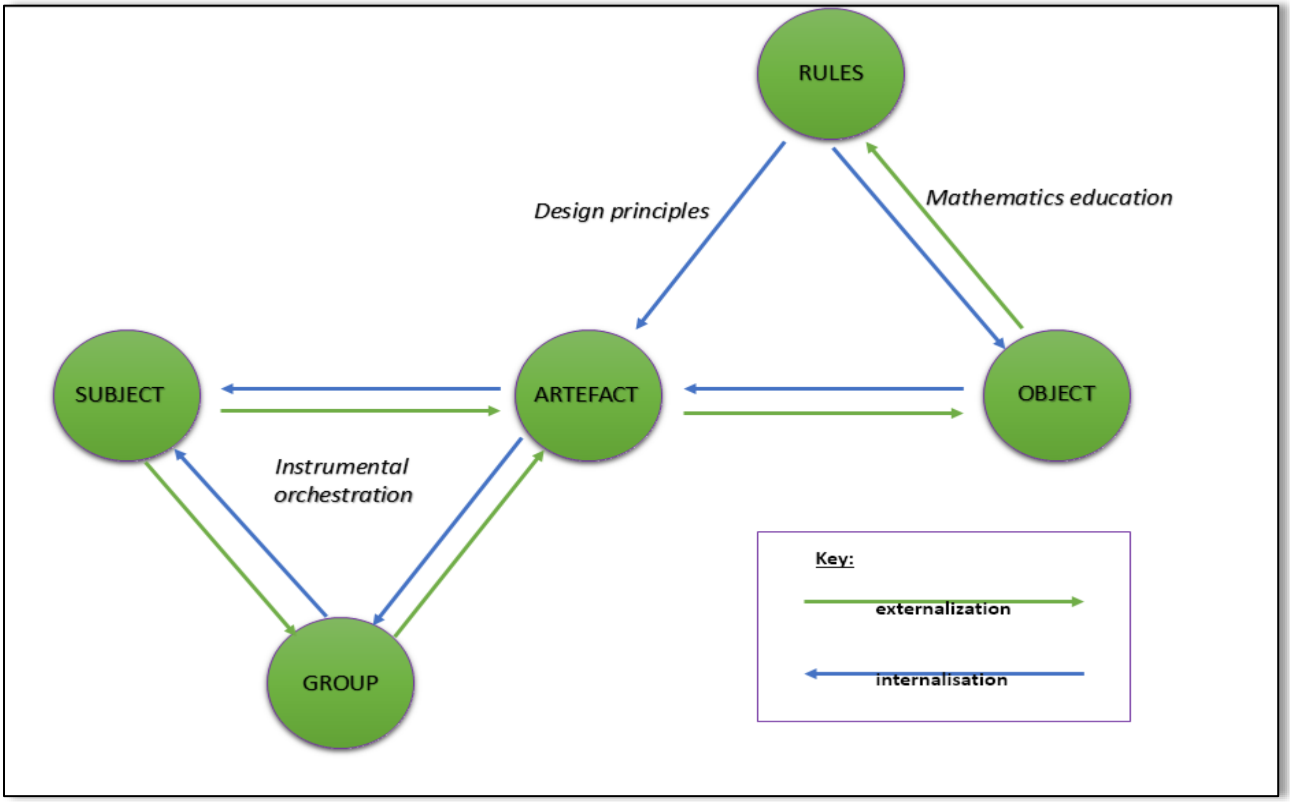

Figure 2.3. Artefact-Centric Activity Theory (ACAT) model (adapted from Vandebrouck et al., 2013, p.190)

According to this ACAT model, Mathematics Education by means of CAI as an activity system, can be described as follows: The *subject* is represented by the learner whose motive (for example master computational fluency with respect to multiplication bonds) directs him towards the *object* (learning content area: numbers and operations). The learner manipulates the object by using an *artefact* (computer) as a digital learning tool. The *artefact* (computer) is responsive to the subject's motives and therefore presents with installed software programmes for teaching and learning of multiplication bonds. The use of artefacts for mastering mathematical tasks (such as mastering the rapid recall of multiplication facts) shapes not only the subject's understanding, but also the teacher's learning of how his/her learners learn.

System *rules* are not only the values and principles underpinning Mathematics education, but also the design and learning principles embedded into the software design that facilitate the subject's meaningful engagement with the mathematical concept (for example multiplication). The peer group or social classroom environment (*group*) represents Engeström's community and division of labour constructs. In doing learning tasks (for example problem solving requiring multiplication) the subject contructs personal meanings related to using the artefact. In mediating this personally constructed meaning to develop into mathematical concepts and skills, the role of the teacher becomes vital. The process leading from personal to mathematical meanings is, according to Vandebrouck et al*.* (2013), not a spontaneous one but one in which the teacher's intentional intensive mediation (orchestration) is required to mediate individual learning. As social interaction is viewed as crucial for learning, the teacher's role to facililtate and mediate mutual understanding in group (class) context becomes equally important.

2.3.3 Learning theories

2.3.3.1 Behaviourism

Mayer (2014) has shown that it is useful to distinguish between two views of learning with digital media: *information acquisition* and *knowledge construction*. From an information acquisition view, learning involves adding information to the learner's memory. In agreeing with Skinner's operant conditioning (Schunk, 1996), the purpose of the digital game is therefore, to present information which the player needs to receive and to retrieve from memory during the game while being rewarded through in-game incentives. The learning environment is non-interactive and the player's input in the game does not alter the game context or gameplay in any manner. The game will play itself out in the same way with all players alike. This process is underpinned by operant conditioning whereby learning is set equal to a stimulus-response process – the software draws correct responses from the player and knowledge is conveyed through transmission as little or no intrinsic motivation or behavioural changes arise that can lead to deep understanding of the content (Groff et al*.*, 2012). Drill-and-practice games fall in this category and are generally used to reinforce lower-level skills (for example mental math).

2.3.3.2 Cognitivist theories

In games genres such as puzzles, quizzes, quests, role-play games and adventure games (where difficulty levels rise as the game evolves), players are able to construct meaning as the game provides them with feedback on their own gameplay. This approach is more learner-centred than behaviouristic games because learning and play are integrated to provide a context that allows for self-regulated learning on the part of the player. In-game motivation is designed in such a way that it facilitates emerging intrinsic motivation within the player. Consistent with Bandura's social cognitive theory, learning takes place in the mind where players make sense of the information that they receive through their senses by means of a wide range of cognitive abilities (for example problem solving skills) (Groff et al*.*, 2012; Orey, 2010;Sedano, 2012).

2.3.3.3 Constructivism

Several researchers found that well-designed educational games adhere to constructivist principles and should therefore lead to improved learner performance. Learning by means of these games involves that the learner is regarded as an active sense-maker: selecting, organising and integrating new information with own prior knowledge while constructing new knowledge independently (Piaget's constructivism) or collaboratively with others in a social setting (Vygotskian or social constructivism) (Dondlinger, 2007; Felicia, 2009; Groff et al., 2012; Jaworski & Potari, 2009; Schunk, 1996; Vandebrouck et al., 2013). Game genres such as action adventure games, war games, sport games, racing games and simulation games that promote situated learning by creating authentic learning environments and/or facilitating cognitive apprenticeship by generating rich social contexts, can be considered as underpinned by constructivist learning theories. In discussing AT, Roth (2002) refers to Engeström (2000) stating that engaging in an *activity* does not only increase learner motivation, but it also opens up a zone of proximal development for mediating the internalisation of new skills and concepts.

2.3.4 Motivation Theories

2.3.4.1 The Control Value theory of Achievement Emotions

Pekrun's (1992) interest in identifying emotions that bear specific relevance to academic achievement commenced more than twenty years ago. Initially, he only studied empirically for test anxiety, and for positive versus negative mood, but soon hypothesised that many other emotions also come into play. As part of a research team, he focussed on qualitative methods towards 2002 and published empirical findings on positive emotions involved in learning and achievement (Pekrun et al., 2002). He identified positive emotions (enjoyment of learning, hope, pride, and relief) as well thus counteracting previous research that mainly focussed on negative emotions (anxiety and frustration) (McLeod, 1992; Pekrun et al., 2011).

As part of a follow-up research project Pekrun et al. (2011) persisted in researching academic emotions. The findings led to The Control Value theory of Achievement Emotions that proposes that enjoyment of achievement activities is instigated when these activities are experienced as both controllable and valuable. Value appraisals relate to the subjective importance of achievement related activities and outcomes. The theory also sets out the categorisation of achievement outcomes into affective, cognitive, motivational, and physiological components. Furthermore, it also refers to the different academic settings in which the emotions manifest and provides a description of emotions in terms of activation (activating or deactivating emotions) and valence (positive and negative emotions). As abovementioned constructs are significant to the current study, it will be discussed in depth in sub-section 2.4.2 of this chapter.

2.3.4.2 Flow theory

Csikszentmihalyi's (1990) concept of optimal life experiences (flow) paved the way towards many motivational theories. He attempted to describe the quality of subjective experiences - what intrinsic motivation would for example feel like. With the current study in mind, his notion of how *skill* and *challenge* interact and influence motivation becomes significant. Csikszentmihalyi's (1990) notion of motivation, cognition and situational affect which are made meaningful by the individual's environment, is also relevant. His characterising of the circumstances in which people are intrinsically motivated to pursue goals, as described by Scheinle and Bjornestad (2009), is equally significant to this study.

Csikszentmihalyi defines Flow as…

> …the state in which people are so intensely involved in an activity that nothing else seems to matter, the experience in itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it (p.4) … we feel in control of our actions, masters of our own fate … we feel a deep sense of exhilaration, a deep sense of enjoyment (Csikszentmihalyi, 1990, p. 3).

To Ghani, Supnick and Rooney (1991) Flow represents…

> the total concentration in an activity and the enjoyment which one derives from an activity... the sense of control over one's environment… the precondition for flow is a balance between the challenges perceived in a given situation and skills a person brings to it (cited in Novak, Hoffman & Yung, 1997, p. 10).

Ellis, Voelkl and Morris (1994) hold a similar position when they define Flow as …

> an optimal experience that stems from peoples' perceptions of challenges and skills in given situations. Situations in which challenges and skills are perceived to be equivalent are thought to facilitate the emergence of such indicators of flow as positive affect and high levels of arousal, intrinsic motivation, and perceived freedom (cited in Novak et al.,1997, p. 11)

Csikszentmihalyi (1990), however, distinguishes between the following *elements* of flow: a) challenging, often rule bound activities that require skill, b)tasks that have clear goals and offer immediate feedback, c) the ability to concentrate on the task at hand, d) a perceived sense of control over one's actions, and the absence of worry about losing control, e) the merging of action and awareness resulting in a state of deep and effortless involvement, f) the loss of self-consciousness or preoccupation with oneself and g) the transformation of a sense of time. Csikszentmihalyi's (1990) model also proposes the balance between skill and challenge as a pre-requisite for flow. When skill overcomes the challenge, the individual will become bored with the task. On the other hand, if the challenge is perceived as more powerful than the skill, the individual will become anxious (Wan & Chiou, 2006; Wentzel, 2014).

Paras and Bizzocchi (2005) view *flow theory* as a theoretical bridge between the ARCS model (and the concerns of digital instructional design. Consistent with the ARCS model, flow theory also states that the learner needs to be provided with appropriate challenges and feelings of control need to be facilitated. While in a state of flow, learners will then be completely motivated to push their own skills to the limit. According to Paras and Bizzocchi (2005), such a state can be described as optimal intrinsic motivation, something that all learning environments can aspire to.

2.3.5 Game flow theories

In literature, the core requirements of *flow* were associated with some essentials of good game design (Nacke, 2008). The subsequent development and importance of game flow models for learning through games, is summarised by Paras and Bizzocchi (2005, p.4) as “since games foster play, which produces a state of flow, which increases motivation, which supports the learning process”. Novak et al. (1997) published an early game flow model in which they connected the elements of flow to characteristics of digital learning environments. Similar game flow models followed: Jones (1998), Sweetser and Wyeth (2005), Cowley, Charles, Black and Hickey (2008), Nacke (2008) and Faiola, Newlon, Pfaff and Smyslova (2013). Since Sweetser and Wyeth’s (2005) model integrate game design characteristics into a well-structured model of enjoyment in games, their GameFlow model of Enjoyment will be utilised as theoretical framework for this study.

2.3.5.1 GameFlow Model of Enjoyment

Apart from focussing on enjoyment, Sweetser and Wyeth (2005) also added a social dimension to interaction – an aspect heavily debated in literature since then as the question of whether social interaction is desirable in all games is raised. This model consists of eight core elements namely concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. Each element corresponds with a varying number of aspects relating to Csikszentmihalyi’s (1990) elements of flow. Csikszentmihalyi’s (1990) first element of flow, ‘*challenging, often rule bound activities that require skill*’ is not directly represented in the model as the entire game portrays this aspect.

The GameFlow components accompanied by the corresponding elements of flow are represented in Table 2.1.

Table 2.1. GameFlow model of Enjoyment (adapted from Sweetser & Wyeth, 2005; Nacke, 2008).

GAMEFLOW COMPONENTS	ELEMENTS OF FLOW FROM CSIKSZENTMIHALYI'S FLOW THEORY
CONCENTRATION	
Games must keep the player's concentration through a high work-load.	The ability to concentrate on the task at hand
CHALLENGE AND PLAYER SKILLS	
Tasks must be sufficiently challenging to be enjoyable The player must be skilled enough to undertake the challenging tasks	Perceived skills should match challenges and both must exceed a certain threshold
CLEAR GOALS AND FEEDBACK	
Tasks must have clear goals so that the player can complete the tasks, and the player must receive feedback on progress towards completing the tasks	Tasks that have clear goals and offer immediate feedback
CONTROL	
If players are sufficiently skilled, the tasks have clear goals and the game provides feedback, then players will feel a sense of control over the task.	A perceived sense of control over one's actions, and the absence of worrying about losing control
IMMERSION	
Abovementioned elements culminate in total immersion or absorption in the game: players lose awareness of everyday life, lose concern about the self, and their sense of time may be altered.	The merging of action and awareness resulting in a state of deep and effortless involvement The loss of self-consciousness or preoccupation with the self The transformation of a sense of time
SOCIAL INTERACTION	
"People play games to interact with other people, regardless of the task, and will even play games they do not like or even when they don't like games at all" (Sweetser & Wyeth, 2005, p. 4)	Social interaction does not correspond with flow theory, but as Sweetser and Wyeth contest that it is highly featured in the literature gamer experience, it is included in their model.

Song and Zhang's (2008) proposed a model offering grounded evidence of the conditions and processes under which learners are able to optimally benefit through computer assisted instruction – not only in terms of cognitive gains, but also in terms of affective gains. As the study strives to understand learners' affective experiences without intentionally investigating cognitive gains, Song and Zhang's (2008) model is preferred over and above the following earlier models that only concentrated on cognitive gains: Cognitive Theory of Learning with Multimedia (CTLM) (Mayer, 2005) and the corresponding extended theory, Cognitive Affective Theory of Learning with Multimedia (CATLM) developed by Moreno and Mayer (2007). Song and Zhang's (2008) will be set out in the following sub-section.

2.3.5.2 EFM model for educational game design

In laying down criteria for educational game design, Song and Zhang (2008) found a close connection between effective learning environments (E), flow experiences (F) and motivation (M). These researchers conclude that when applying rational well-researched design principles, educational game contexts and experiences can serve as effective learning environments. While actively learning by means of games, learners experience flow and subsequent high levels of intrinsic motivation, resulting in enhanced transfer of attained knowledge and skills.

Song and Zhang (2008) based their framework on flow theory as shown by Csikszentmihalyi (1990). They categorise Csikszentmihalyi's flow elements into three sub-groups: *conditional factors* (challenge-skill balance, clear rules and goals of the activity, and unambiguous feedback); *experience factors* (concentration, control and merging of action, and awareness) as well as *result factors* (autotelic experiences[4], transformation of sense of time and loss of self-consciousness). Concerning motivation, Song and Zhang (2008) assert that to elicit, inspire and maintain motivation is the first step towards the design of environments that are conducive to learning. They follow Keller's (1987) ARCS model by explaining motivation elements as follows:

A*ttention* strategies for arousing and sustaining learners' curiosity and interest; ***R****elevance* strategies that link to learners' needs, interests, and motives; ***C****onfidence* strategies that help learners develop success expectations and ***S****atisfaction* strategies providing extrinsic and intrinsic reinforcement for learner effort.

Song and Zhang (2008) proclaim effective learning environments as positive learning climates that not only assist learners to understand and master learning content, but also raise self-awareness on the part of the learners. They follow Houser and DeLoach (1998) to the letter when adopting their principles for effective learning with games. The seven principles are: a) provide a high intensity of interaction and feedback; b) set specific goals and established procedures; c) motivate; d) provide a continual feeling of challenge that is, neither so difficult as to create a sense of hopelessness and frustration, nor so easy as to produce boredom; e) provide a sense of direct engagement, producing the feeling of directly experiencing the environment, directly working on the task; f) provide appropriate tools that fit the user and task so well that he can get aid and do not distract, and g) avoid distractions and disruptions that intervene and destroy the subjective experience.

Figure 2.4 illustrates the EFM model for Educational design that highlights the interconnectedness between the constructs depicting motivation, flow experiences and environments conducive to learning. Song and Zhang (2008) hold that a synergy between these constructs (complimented by strong design criteria) will result in cognitive as well as affective gains on the part of the learner as educational game player.

[4] **Autotelic experience** refers to "a self-contained activity, one that is done not with the expectation of some future benefit, but simply because the doing itself is the reward (Csikszentmihalyi, 1990, p. 67)

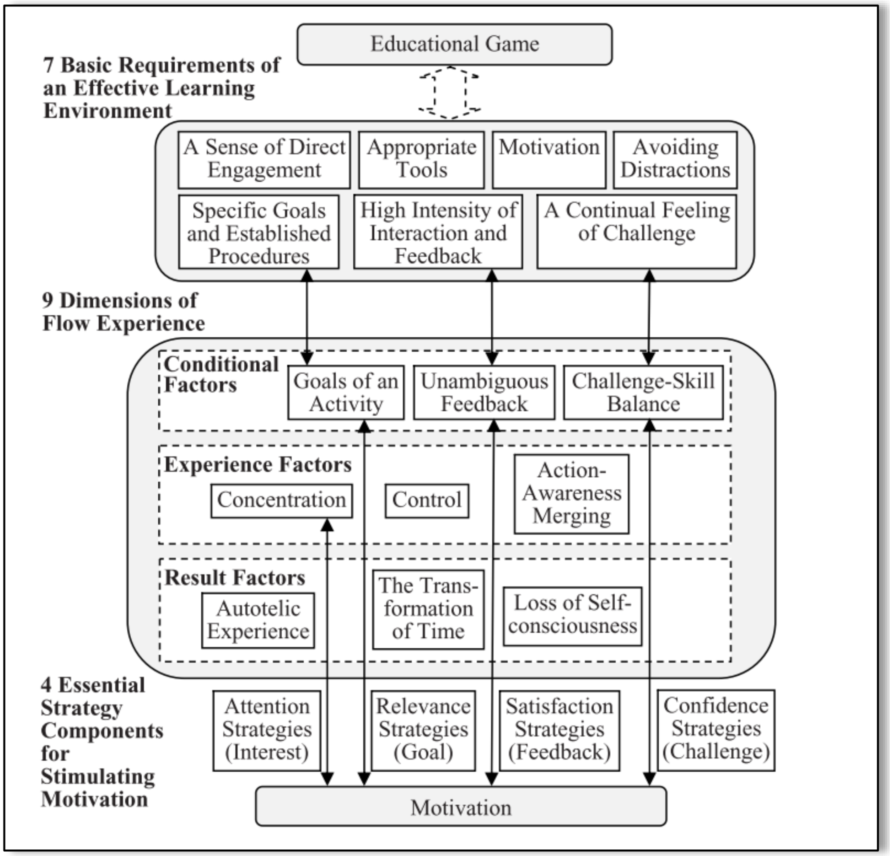

Figure 2.4. EFM model for educational game design (Song & Zhang, 2008, p. 513)

The literature review will reveal research findings on the role of affect in Mathematics education. Attention to beliefs, attitudes and academic emotions in Mathematics education as subsets of affect will follow.

2.4 The Role of Affect in Mathematics Education

There is an increasing recognition that affect plays a critical role in the teaching and learning of mathematics as it interacts (sometimes interferes) with the acquisition of skills, the effective storing of information and the successful retrieval thereof from memory (Belbase, 2011; Haase et al., 2012; Mandler, 1989; McLeod, 1992; Pekrun et al., 2002).

Despite a seeming lack of research regarding the role of effect on performance in Mathematics during middle childhood (5-9 years), considerable insight has been gained regarding affect as construct in the context of studies involving older learners (Eden et al. 2013). McLeod (1992) presented an overall theoretical framework consistent with research study findings from 1970-1992 and defines the affective domain as a “wide range of beliefs, feelings and moods that are generally regarding as going beyond the domain of cognition” (McLeod, 1992, p.576). McLeod (1992) therefore divides the affective domain into beliefs, attitudes and academic emotions.

An analysis of the extensive review of literature on affect in Mathematics education by Haase et al. (2012) reveals that research interest in the role of affect waned around the turn of the century and those who diligently continued, frequently only relied on quantitative methods of investigation. Those turning towards qualitative investigations often left a trail of ethical questions that could implicate findings (Haase et al., 2012). Leder and Forgasz (2006), however, suggested that quantitative methods should be used for investigations of *attitudes* and *beliefs* whereas qualitative methods are advisable in investigating *emotions* and *values*.

Both McLeod (1992) and Haase et al*.* (2012) confirm a distinctive separation between cognitive and affective domains in Mathematics education and share the opinion that the affective domain should receive more attention in terms of curriculum development, teacher education and research in Mathematics teaching and learning.

2.4.1 Beliefs and attitudes

Beliefs are central to the development of attitudinal and emotional responses to Mathematics (Schoenfeld, 1989; McLeod, 1992). Beliefs refer to learners' subjective knowledge about 1) mathematics, 2) the self (self-concept as well as mathematical self-concept), 3) the teaching of Mathematics and 4) the social context of teaching and learning Mathematics (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; McLeod, 1992). Stodolsky (1985) stresses that learners' beliefs about Mathematics change as they grow older, if content that was once viewed as difficult is mastered over time and the belief about the subject is altered. Likewise, when 'gaps' in basic content knowledge and skills should occur, beliefs are also adjusted. McLeod (1992) asserts that beliefs and attitudes are almost inseparable; with changes in belief, attitudes also change as attitudes are "affective responses that involve positive and negative feelings of moderate intensity and stability" (McLeod, 1992, p. 581). McLeod (1992) also points out that attitude towards Mathematics should not be viewed as one-dimensional as a learner could have a positive attitude towards geometry and a negative attitude towards algebra or any other component of Mathematics.

Mathematical self-concept is closely linked to metacognition (the self-monitoring of control and thought), self-regulation (consistent pursuing of self-chosen learning resulting from metacognition), academic self- awareness (ability to engage in academic introspection) and the learner's intrinsic motivation to self-regulate (Schunk, 1996; Stodolsky, 1985; Kislenko, 2006; Kislenko, Grevholm & Lepik, 2006). Positive links have been established between good Mathematical self-concept and achievement in Mathematics (Marsh, 1986).

Beliefs about the self are connected to self-concept; self-confidence and causal attributions for success and failure. In this regard Weiner and Weiner (2004) contest that boys are more likely to attribute their successes to ability whereas girls tend to attribute their successes to additional effort expended. When it comes to personal failure, girls (more than boys) attribute it to lack of ability (learned helplessness).

Beliefs about Mathematics teaching and the social context of Mathematics learning and teaching; McLeod (1992) found that very little empirical evidence about learners' beliefs about Mathematic teaching exists. Carter and Yackel (1989), however, found that the beliefs of girls regarding Mathematics often reflect the social norms as expressed by their parents/caregivers during primary school. Research by Berkowitz et al. (2015) affirms that highly math-anxious parents/caregivers provide a low quality of math input in their home(s) and that regular (even brief) brief, high-intensity interactions about mathematics in a playful manner, can break the cycle of intergenerational low achievement in Mathematics. In addition to these findings, Maloney, Ramirez, Gunderson, Levine and Beilock (2015) also affirms that when math-anxious parents/caregivers should (through good intentions) regularly assist their children in homework tasks in a formal, non-playful manner, their own Mathematics anxieties manifests in their children and achievement deteriorates. Less homework interaction by math-anxious parents/caregivers, caused increased performance. The supportive role of parents/caregivers, peers and teachers in the construction of a positive mathematical self-concept in girls as well as boys must therefore never be negated (Belbase, 2011). Cultural factors, especially the cultural classroom setup, also play an important role in beliefs concerning Mathematics. The belief in inbred mathematical ability is differently valued by different culture groups (Schoenfeld, 1989).

2.4.2 Academic emotions

The term *academic emotions* to describe the feelings or emotions (affect) directly linked to learning, classroom instruction was coined by Pekrun et al. (2002). These authors assert that learners experience a variety of emotions in academic settings that influence their perceptions and behaviour (including academic performance) in specific domains of learning (subjects). The major academic emotions are enjoyment, hope, pride, anger, anxiety, shame, hopelessness, confidence, relief and boredom.

Significant research contributions were made by Pekrun et al. (2011) who explain that, anxiety (for example) is made up of uneasy and tense feelings (*affective component*), worries (*cognitive component*), impulses to escape from the situation (*motivational component*), as well as peripheral activation (*physiological component*). Levenson (2003) elaborates on the physiological component by stating that, apart from language, emotions are communicated to others by means of a set of signs and signals.

Although facial expressions and vocalisations attract most attention, there is also a set of appearance changes of autonomic origin brought about by peripheral activation of the nervous system for example pupillary constriction and dilation and secretion of saliva. These involuntary processes show others what we are feeling in ways not consciously brought about. Recent research findings by Bahreini, Nadolski, and Westera (2016) confirmed that visual and auditory information can be used to develop software programmes (for example FILTWAM) being able to recognize the affective state of a computer user or, more specifically, a computer game player by analysing facial expressions, gestures, body movements and voice intonation. Unfortunately, this research only included the six basic and general emotions (happy, sad, surprise, fear, disgust, and anger with neutral as counterbalance) posited by Ekman (1992) and did not focus on the entire array of academic emotions.

Another significant factor regarding the nature of academic emotions is the diversity thereof: Pekrun et al. (2011) indicate that research on academic emotion should acknowledge emotional diversity in academic settings by addressing the full range of emotions experienced by learners and not study a specific emotion in isolation. They also contest that emotions can affect learners' achievement as well as their interest, engagement, and personality development, in addition to affecting the social climate in classrooms and educational institutions. To elaborate on Pekrun et al.'s (2011) categorisation of academic emotions, the different constructs will henceforward be exposed:

Valence and activation of academic emotions: Pekrun et al. (2011) distinguishes between positive activating (enjoyment, hope and pride), positive deactivating (relief), negative activating (anger, anxiety and shame) and negative deactivating emotions (hopelessness and boredom) (Figure 2.5). Positive activating emotions may result in both extrinsic and intrinsic motivation, supporting self-regulation. Negative activating emotions, on the other hand, reduce motivation and effortful information processing, negatively influencing performance whereas negative activating emotions may cause lower intrinsic motivation. It may enhance extrinsic motivation in the sense that the learner could apply more effort to prevent future shame caused by failure.

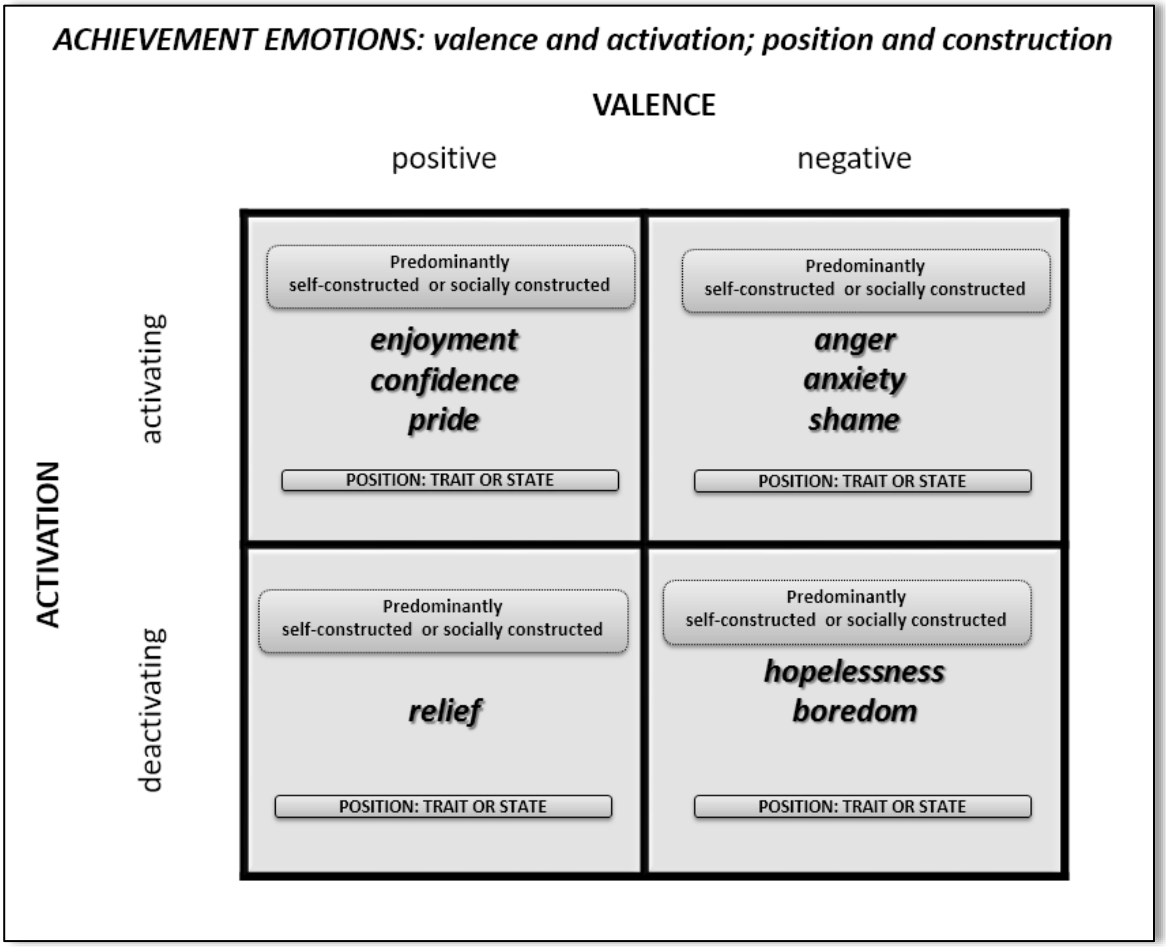

Figure 2.5. Academic emotions: matrix describing valence and activation; position and construction (adapted from Pekrun, 1992; Pekrun et al., 2002 & Pekrun et al., 2011)

Outcome focus of academic emotions: Pekrun, Maier and Elliot (2006) contest that the outcome focus of academic emotions are determined by an individual's extent of control over and value appraisal of the specific academic emotion to be experienced.

When classified in terms of types of *focus*, (Figure 2.6) enjoyment, boredom and anger can predict *specific activity outcomes*. Expectancies of an action that can be initiated and performed by the individual, are raised (Pekrun, 2002). These self-efficacy expectations (whether low or high) may lead to different outcome focus on the part of the student. Whereas *enjoyment*, may result in high self-efficacy and task pursuance, the focus is not necessarily on achievement. The student completes the task simply because he finds joy in doing it. *Boredom* and *anger*, on the other hand, may also lead to task acceptance accompanied with feelings of low self-efficacy when the activity lacks any incentive value. The student accepts the task and will probably complete it due to submission to authority and not as result of having achievement goals in mind (Pekrun et al., 2006).

Confidence (hope to succeed) and pride point to the *achievement outcomes approach* where mastery goals are pursued. As pre-requisite, the activity needs to be experienced as both controllable and valuable. A student is, for example, expected to feel confident about mastering a task when he feels competent and when he perceives the learning material as valuable – worth studying. Although not yet declared competent, the confidence with which he studies, results in '*pride* without prize' (Pekrun et al., 2002, 2006, 2011).

Emotions of *anxiety, shame and hopelessness* would lead to *performance avoidance* as it is related to potential failure. These emotions are thought to arise when there is lack of control on the part of the student due to uncertainty about these achievement outcomes, paired with subjective importance thereof. A student would, for example, feel anxious before an exam should he perceive the exam as important; yet still expect failure. The student would then focus on how to avoid taking the exam instead of focus on the desired activity (to study).

Relief and gratitude are described as *retrospective* outcome emotions due to the external origin thereof – something that the student does not have control over. For example: when a test is postponed, the origin of the decision was external and the student lacked control thereof. In retrospect, the student may experience emotions of *relief* and *gratitude* (Pekrun, 1992; Pekrun et al., 2002, 2011).

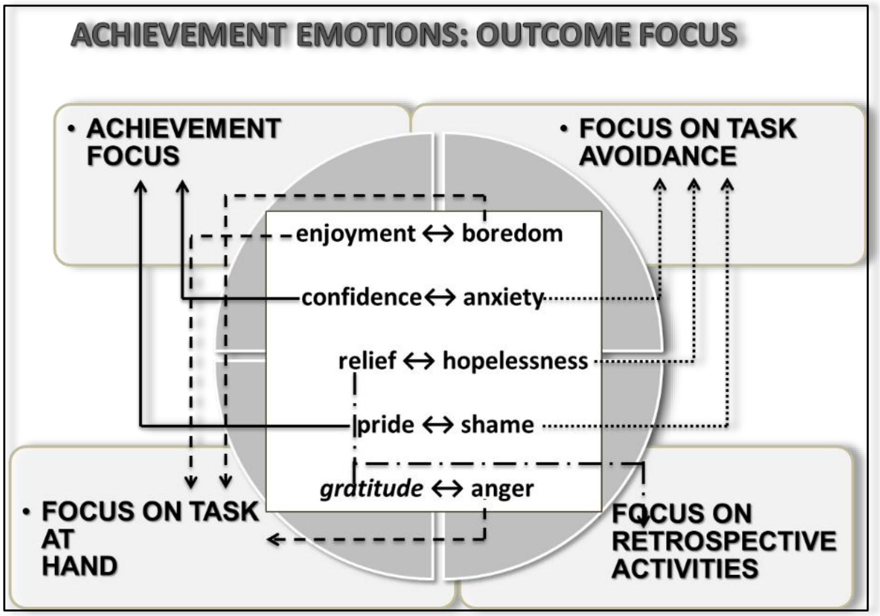

Figure 2.6. Academic emotions: outcome focus (adapted from Pekrun, 1992; Pekrun et al., 2002, 2011)

Although Pekrun et al*.* (2011) did not include '*gratitude*' in their list of nine academic emotions, it was used in Pekrun (1992) to counterbalance 'anger' as an academic emotion. To logically expose outcome focus, gratitude is included as a positive valence to 'anger'.

In accordance with Belbase (2011), who asserts that all academic emotions related to mathematics stem from an interaction between socially and personally constructed images, Pekrun et al. (2011) also relate to academic emotions being situational (contextual) and temporal (time-based) specific. Belbase

(2011) expresses that an emotion felt in an academic situation (although influenced by socially and personally constructed past experiences), is always predominantly socially or personally constructed in a specific context (in- or outside class context).

In contrast to Pekrun et al. (2002), Belbase (2011) not only refers to cognitive, behavioural and affective domains, but also agrees to the temporal state of emotions in stating that an academic emotion (for example anxiety) can be a *trait* or *state* position. Trait refers to where feelings of fear are experienced in any situation associated with the specific fear. State anxiety, on the other hand refers to short-lived emotional states which are consciously and subjectively perceived and may include heightened automatic nervous activity as well. Course specific anxiety (for example Mathematics anxiety) can therefore refer to a position (state) where anxiety is sporadically experienced in and associated with specific contexts. It can also be a chronic situation (trait position) where exposure to any form of mathematics in any context would heighten anxiety (Belbase, 2011; Pekrun et al., 2002). Due to this expansion, Pekrun et al. (2011) distinguish between three different in-class related emotions: emotions experienced while attending class, emotions experienced learning in class and emotions experienced when assessments (tests) are conducted.

To summarise affect in Mathematics education, Figure 2.7 on the next page provides a framework on academic emotions and other related constructs as outlined in sub-section 2.4.

To enable better understanding of Figure 2.7, a brief orientation follows: The figure resembles a matrix (as depicted in chapter 5, figure 5.3) that was used to code participants' observed academic emotions while reflecting on the personal processes of automatising of multiplication tables in school and home learning environments. The matrix is formed by the interplay between the origin of participants' beliefs and attitudes (about Mathematics, the self, the social context of learning Mathematics and the context of teaching and learning Mathematics) and the different domains (intrinsic to the learner) in which a specific academic emotion can be formed (cognitive, affective, physiological and motivational domains). The following example can be put forward: Should a learner be expected to answer multiplication table questions during a speed drill exercise in front of his/her peers in class, the learner may experience severe anxiety as one of the ten major academic emotions. The origin domains could therefore be identified as 'cognitive' on the one hand and beliefs about the 'social context of learning and teaching Mathematics' on the other. To pinpoint the domain(s) with more accuracy, the entire context in which the emotion was experienced, needs to be scrutinized.

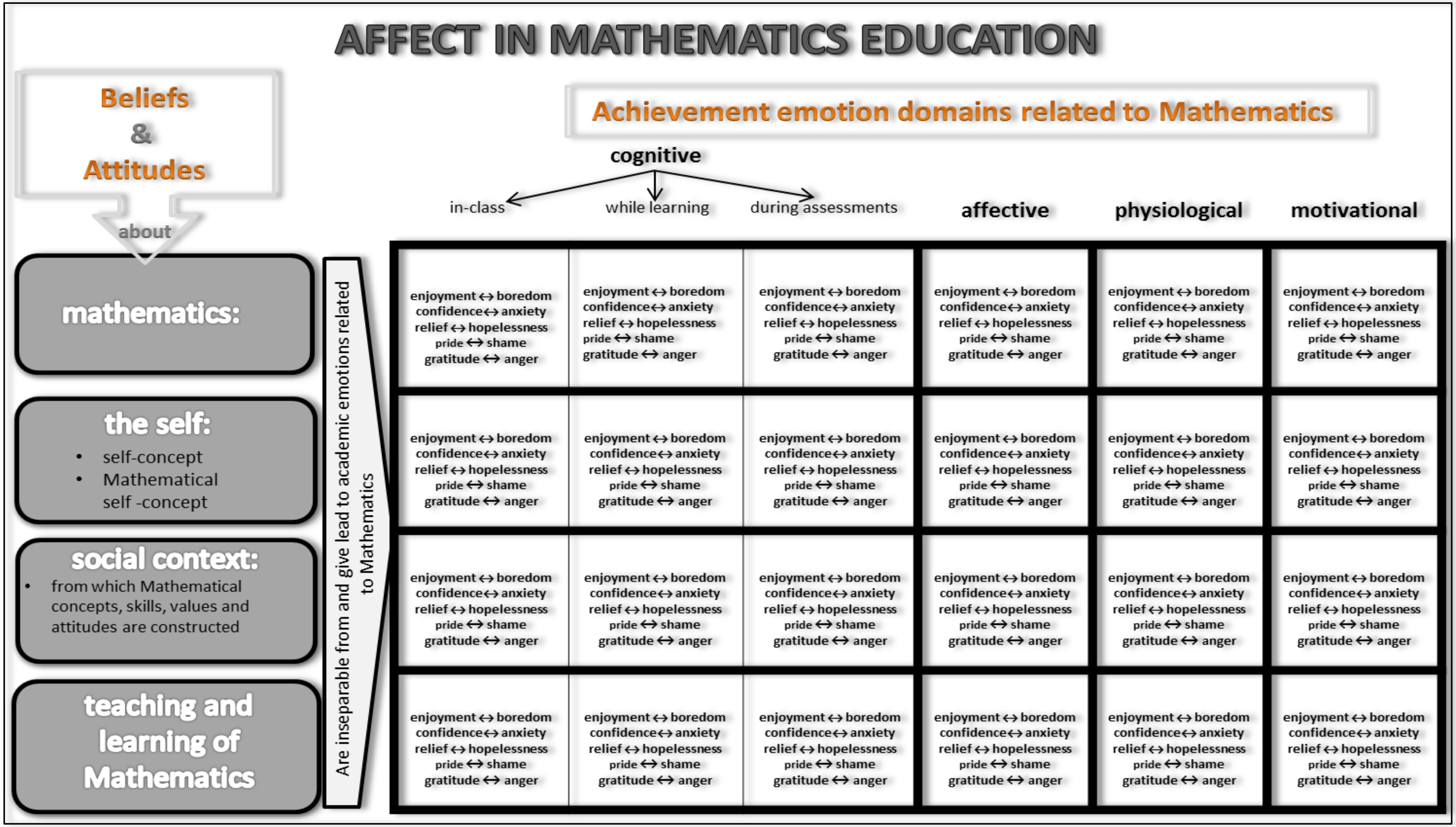

Figure 2.7. Affect in Mathematics Education (adapted from Belbase, 2011; Eden et al., 2013; Haase et al., 2012; Mandler, 1989; McLeod, 1992; Pekrun, 1992; Pekrun et al., 2002, 2011 & Strawderman, 2010).

As study interprets learners' anxiety experiences that could have resulted from an imbalance between *challenge* and *skill* (Wan & Chiou, 2006; Wentzel, 2014) in the automatisation of multiplication facts, an in-depth study of *confidence* ↔ *anxiety* valence[5] in the learning of mathematics was called for:

2.4.3 Mathematics anxiety

Mathematics anxiety (MA) was initially defined as "an irrational dread" and "feelings of tension" when "manipulating numbers" (Buckley & Ribordy, 1982; Richardson and Suin, 1972 as cited in Gierl and Bersanz, 1995). As research expanded, the Mathematics anxiety construct was unravelled as negative emotional, mental as well as physical responses strongly associated with negative beliefs and attitudes towards mathematics. It is characterised by avoidance of situations involving mathematics in a variety of situations - academic as well as ordinary life situations; always accompanied by feelings of helplessness, mental disorganisation, stress, anxiety and even dread that threaten a person's self-esteem *(*Arem, 2009; Ashcraft and Moore, 2009; Ashcraft and Ridley, 2005; Belbase, 2011; Faust, Ashcraft & Fleck, 1996).

Apart from the abovementioned characteristics, research had produced unanimous findings on Mathematics anxiety directly impacting on the span of the working memory, especially when dealing with arithmetic. Anxious thoughts and feelings consume the brain's working memory resources, cramping memory resources required for storing or retrieval of computational facts. As a result, automaticity remains outside the reach of the anxious individual (Ashcraft and Kirk, 2001; Hembree, 1990; Scarpello, 2007). It is, however, important to take cognisance of the fact that no thorough empirical evidence describing a causal relationship between Mathematics anxiety and performance in general exists yet. Mathematics anxiety could potentially disrupt performances that rely on working memory such as computational fluency (Ashcraft, 2002). In contrast, Ramirez et al. (2013) found that learners with a *large* working memory span may be most susceptible to the effects of Mathematics anxiety. These effects will not necessarily have cognitive implications, but huge affective implications. As these learners arguably have higher mathematical learning potential, Ramirez et al.'s (2013) findings are particularly worrisome as it implies that Mathematics anxiety could impair learners' ability to fulfil their own potential. Wu et al. (2012) confirmed Ramirez et al.'s (2013) later findings stating that even average and above-average performers could fall prey to Mathematics anxiety at the earliest stages of formal Mathematics education.

Recent research by Vukovic, Kieffer, Bailey and Harari (2013) produced empirical evidence about the somatic symptoms associated with Mathematics anxiety whereas previous research by Dowker et al., (2012) and (Reddy et al., 2015; Frempong, Yu & Winnaar 2015). (2010) assumed that these symptoms were similar to general anxiety. Dowker et al. (2012) only mentions psychosomatic symptoms whereas Wei (2010) and Vukovic et al. (2013) qualify these symptoms as: rapid pulse rate, nervous stomach, heart palpitations, tension headaches, visibly upset feelings expressed through sudden changes in behaviour and sweaty palms. Wang et al. (2014) concluded that learners with diagnosed general anxiety and low levels of Mathematics cognition are prone to display Mathematics anxiety. Opposed to general anxiety of which stressors have been well-defined, the stressors (anything physical or psychological that produces

[5]Term used to characterise and categorise specific emotions; denoting intrinsic attraction (positive **valence**) or aversion (negative **valence**) of an event, object, or situation. Throughout this study a symbol (↔) will be used to indicate the valence between two different academic emotions.

stress) connected to Mathematics anxiety are only vaguely described as factors within the different Mathematics anxiety domains described sub-section 2.4.3.1.

2.4.3.1 Mathematics anxiety domains

Researchers tend to put forward models in explaining the complexities of the Mathematics anxiety construct (Arem, 2009; Ashcraft, 2002; Ashcraft & Moore, 2009; Cavanagh & Sparrow, 2011). Although these models vary in terms of internal structure, all emphasise a clear distinction between the affective and cognitive domains as proposed by Wigfield and Meece (1988). Strawderman (2010) distinguishes between intellectual (failure ↔ success), social (avoidance ↔ pursuit) and psychological (anxiety ↔ confidence) domains. Each domain is described as a valence of two variables as shown in brackets. Strawderman (2010) clarified the social domain as influences of family, peers and society as a whole. The psychological domain is defined by affective attributes. It mainly comprises of the individual's emotional history and the different affective reactions to stimuli. The intellectual domain includes influences of a cognitive nature. In contrast, Berch and Mazzocco's (2007) model focusses on various developmental, etiological and educational factors and also advances a negative feedback loop resulting from mathematics anxiety. Recent models postulated by Cavanagh and Sparrow (2011) and Belbase (2011) highlight attitudinal, cognitive, emotional as well as somatic indicators related to MA.

2.4.3.2 The onset of Mathematics anxiety

Literature reveals discrepant research findings: Berch and Mazzocco (2007) believes that Mathematics anxiety will begin to appear around the sixth school grade whereas Dowker et al. (2012) and Sheffield and Hunt (2006) claim the onset to be in the fourth grade. Jansen et al. (2013), Ramirez et al. (2013) as well as Maloney and Beilock (2012) refute these claims and contest that Mathematics anxiety could impact on the performance in Mathematics as early as first and second grade. Boaler (2015) provides clarity on the onset of mathematics anxiety by asserting that the moment a learner is exposed to rote memorisation in the name of computational fluency, teachers and/or parents/caregivers are putting learners at risk of becoming fearful of Mathematics; simultaneously endangering optimal functioning in an ever-quantitative society and inhibiting positive affect towards the discipline of mathematics.

2.4.3.3 Causes of Mathematics anxiety

Many researchers agree that the antecedents of Mathematics anxiety remain largely undetermined. Others attempt to classify the causes and elaborate on them. Rubenstein and Tannock (2010) identified three categories; environmental, personal and cognitive causes. The following possible causes were outlined by various scholars:

Environmental causes: inappropriate teaching styles (Ashcraft, 2002), negative classroom experiences, parents'/caregivers' negative attitudes towards Mathematics, poor past performances (Scarpello, 2007), behaviouristic teaching approaches (Newstead, 1998), learner absenteeism (Tobias & Weissbrod, 1980) and unrewarding and /or discomforting life experiences with mathematics (Arem, 2009). *Personal causes:* self-doubt, lack of confidence, negative attitudes (Wei, 2010) and general psycho-social vulnerabilities resulting in lower self-esteem (Berch & Mazzocco, 2007). *Cognitive causes:* failure to learn fundamental skills (Wittman, Marcinkiewicz & Harmony-Douglas, 1998) and rote memorisation (manipulation of symbols without conceptual understanding) (Newstead, 1998). Chinn et al. (2013) and Boaler (2015) added to this by specifically implicating mental arithmetic.

2.4.3.4 Research on Mathematics anxiety in middle childhood (5-9 years)

Most of the studies that were accessed on the role of affect in Mathematics education, involve pre-adolescents to adults. There is, however, a growing body of scholarship confirming the roots of Mathematics anxiety in middle childhood. Sadly these studies seem to produce even less clear evidence on the causal relationship between Mathematics anxiety and performance in Mathematics and display conflicting findings. Krinzinger et al.'s (2009) research (despite the fact that it was a longitudinal study and that only addition and subtraction operations were incorporated in their measurement of performance) could, however, not find any correlation between Mathematics anxiety and general performance in Mathematics.

Studies incorporating all four of the basic operations by Vukovic et al. (2013) and Jansen et al. (2013) stressed that a strong relationship between emotional experience of mathematics (learners' self-perceived competence caused the level of confidence in mathematics) and actual performance in Mathematics exist. In contrast, a study by Aarnos and Perkkilä (2012) that also only used addition (+) and subtraction (–) operations, revealed a slight correspondence between Mathematics anxiety and performance. This study, notably, involved a more developmentally appropriate Mathematics anxiety rating scale measurement than other studies as they used pictures in their adaptations of rating scales developed for older learners. In their own inventions of Mathematics anxiety rating scales for younger learners, Punaro and Reeve (2012) designed a unique measurement instrument involving many picture associations. As a result, they did observe a negative association between high Mathematics anxiety and performance in Mathematics.

Haase et al. (2012) gathered extensive existing research evidence on the relationship between Mathematics anxiety and performance in Mathematics. They were unable to trace any qualitative research findings and concluded that the relationship between Mathematics anxiety and performance in Mathematics is complex and two folded. Their research suggested that it is paramount to look not only at studies reporting on the effect of Mathematics performance on Mathematics anxiety, but also the effect of Mathematics anxiety on performance in Mathematics.

From these discrepancies, it appears as if in contrast to studies involving older learners; the nature of the Mathematics anxiety rating scale as well as the nature of mathematical problem setting (operations to involve in measurement of performance) could have a detrimental effect on research outcomes. Ashcraft and Faust (1994) confirmed that Mathematics anxiety had a minimal impact on simple arithmetic problems but had substantial impact on more difficult multiplication problems. From the exposed contradicting findings, the following suggestions arise: young learners are either not affected by Mathematics anxiety, they do not understand anxiety-related questions when not adapted to their specific developmental level, or they are unable to report their anxieties (if any) in ways adults perceive them to do or are not affected when simple computations that are already automated, are retrieved from memory.

Studies on the causes of Mathematics anxiety that involved younger learners revealed some additional causes not observed in older learners and adults. Cates and Rhymer (2003) highlight the detrimental effect of rote-learning and drilling - aggravating and creating Mathematics anxiety and lowering subsequent performances in mathematics. A study aimed at tracing the roots of Mathematics anxiety (Maloney, Risko, Ansari & Fugelsang, 2010) involved adults with Mathematics anxiety and revealed basic computational level deficit as a potential cause. If these individuals were in the early school grades in the 1980's and 1990's it can be deduced that rote learning drill and practice methods were implemented to obtain fluency. Unfortunately respondents were not requested to elaborate on this topic as the research design was a quantitative experiment. These authors found that poor visual-spatial processing skills impacted on the way mathematical symbols are perceived, thus possibly causing anxiety due to the fact that although concepts are formed, it cannot necessarily be reproduced on paper.

Wu et al*.* (2012) also recognised underperformance (not only poor ability) as a potential cause of Mathematics anxiety in young learners. They reported that underperformers are more prone to Mathematics anxiety than learners with lower mathematical ability. These findings correspond with that of Ramirez et al*.* (2013) on a large working memory capacity as explained in sub-section 2.2.3.1.

Teaching and learning strategies also came under scrutiny in studies involving younger learners. Stuart (2000) contests that Mathematics anxiety is not brought about by mathematics itself, but through the way in which it is taught during early school years. Vukovic et al*.* (2013) elaborate on this warning about inquiry based constructivist strategies that do not enable enough teacher support in acquiring fluency. In contrast, Scarpello (2007) and Boaler (2015) raise concern about more behaviouristic methods such as *repetition* and *speed-te*sts that could undermine a learner's natural thinking processes and lead to a negative attitude towards mathematics. Bottom-line: research findings are inconclusive. Findings seem to depend on the approach, participants and specific case in question.

2.4.3.5 Alleviation of Mathematics anxiety

Since Hembree (1990) much has been written on alleviating Mathematics anxiety (for example Arem, 2009; Curtain-Phillips, 1999; Furner & Duffy, 2002; Tobias, 1993). There, however, seems to be a lack of empirical evidence regarding the outcomes of suggested treatments. Little scholarly work and no longitudinal studies could be found. Suggested intervention programmes consist of psychological treatments (for example cognitive behaviour therapy) and classroom interventions (for example structured mathematics courses, corrective feedback, accommodation of various learning styles, positive psychosocial classroom atmosphere, modelling problem solving, instructional games and computer assisted instruction (CAI) (Wei, 2010). In a more recent study by Gan, Lim and Haw (2015) the researchers found that listening to sedative music (music with a small dynamic range and slow tempo of 60 to 80 beats per minute) while engaging in mathematical problem solving, did lower learners' mathematics anxiety levels.

Researchers are in agreement that intervention should commence during early school years and that it should address both affective as well as cognitive aspects of Mathematics anxiety to contribute to a better understanding of the phenomenon (Vukovic et al., 2013; Wigfield & Meece, 1988). It also stands to reason that Mathematics anxiety can be overcome by improving performance in Mathematics (Sun & Pyzdrowski, 2009). Haase et al. (2012), however, stress the fact that low performance in mathematics does not necessarily immediately elicit negative feelings towards mathematics. This not only justifies, but also drives early intervention to prevent low performance from triggering a cycle of math anxiety and avoidance of mathematics. In their study with second and third graders, Wu et al*.* (2012) found that basic computational skills must be automated as early as possible, as it may combat and alleviate MA, but it could also prevent it.

2.4.3.6 Mathematics anxiety rating scales

Many a rating scale has been developed in pursuing empirical findings on Mathematics anxiety in relation to other variables – mostly performance in mathematics. Eden et al*.* (2013) summarise that major rating scales developed since 1972 clearly display that interest in rating scales for younger learners only developed in recent years. The nature of statements / question items is more appropriate to the developmental level of learners in early childhood. Examples of these rating scales are: Scale for Early Math Anxiety (SEMA) (Wu, et al., 2012); Pictorial test for early signs of math anxiety (Aarnos & Perkkilä, 2012) utilising a smiley face type Likert-scale: ☺ 1= joyful 😐 2 = neutral ☹ 3 = sad; Child math anxiety questionnaire (Ramirez et al., 2013) and a 12-item mathematics anxiety scale (Vukovic et al*.,* 2013). Some authors, however, commented on the use of rating scales for younger learners by arguing that these learners may experience difficulty in making realistic assessments of their own performances (Wigfield et al*.,* 2002). They also asserted that young learners may be inclined to rate themselves too high at such an age (Lehner, 2008). Gierl and Bisanz (1995) also criticised the tendency to only use quantitative measures and suggested that more converging evidence should be obtained when qualitative studies using questionnaires and behavioural observations are also conducted. As far as could be ascertained, no qualitative studies or studies applying mixed research methods have yet been conducted to investigate Mathematics anxiety during middle childhood years.

2.4.3.7 Psycho-physiological computing (affective computing)

The expression of academic emotions consists of intricate combinations of verbal as well as non-verbal information, conveyed through various sources of both body and brain (Ahn, Bailenson, Fox & Jabon, 2010; Darwin, 1965; D'Mello, Picard & Graesser, 2007; Fairclough, 2008; Picard & Daily, 2005). These non-verbal modes of expression may include gestures (Ahn et al*.*, 2010; Pease & Pease, 2008; Wallbott, 1998), postures (Ahn et al., 2010; Sanghvi et al., 2011; Woolf et al*.*, 2009), body movements (Kapoor, Burleson & Picard, 2007; Wallbott, 1998), vocal interjections (Ahn et al*.,* 2010) and facial expressions. Ahn et al. (2010) stresses that the face can be considered the richest source of non-verbal information. Busso et al. (2004) echoes this by stating that although verbal input by means of self-expressed emotional experiences may never be negated, it is feasible and accurate to recognise human emotions from a person's tone of voice and facial expression(s) preferably by means of human-computer interaction.

Ekman (2007) headed a team consisting of many different researchers over the period 1993 to 2007 (Ekman, Friesen & Ellsworth, 2013). Although the team members varied over the years, facial expressions remained the sole research focus. By drawing on the work of Darwin (1965) they recorded more than 10 000 different facial expressions and classified them into six emotion families - happy, sad, fearful, angry, surprised and disgusted. These categories were extended into twenty-two compound families by Du, Tao and Martinez (2014) as they argued that combinations of the six families gave rise to distinctly different emotions.

Although the research subjects were from Caucasian, Asian, African American and Hispanic ethnic groups, the research findings sparked a current research debate on cultural differences in expression of emotion. This contradicted previous findings of universal expressions of emotion across cultures (Ekman & Friesen, 1971). Furthermore, Arroyo et al*.* (2009) remained cautious about pinpointing emotions by observing facial expressions as they felt that the research findings were based on simulated emotions that did not lead to spontaneous facial expressions. Abovementioned scholars were nevertheless in accordance to the fact that, by analysing facial expressions, emotions that are unconscious and not susceptible to social 'editing' (as in the case whereby emotions are conveyed through speech) can be studied (Arroyo et al., 2009; D'Mello et al., 2007; Fairclough, 2008, Pease & Pease, 2008). These facial expressions are (according to aforementioned authors) created by contractions of facial muscles, eye blinking, eye movements, pupillary responses and head tilting.

Fairclough (2008) as well as Ahn et al. (2010) specifically refer to emotions in the context of mathematics education. They stress the fact that social rules can regulate socially appropriate manifestation of emotion. They suggest that multidimensional psycho-physiological measures need to be applied when capturing academic emotions. Fairclough (2008) refers to psycho-psychological computing as innovative human computer interactions whereby covert psycho-psychological data can be monitored, analysed and responded to by means of real time computerised support in terms of the analysis and findings. The type of support may vary from offering tutoring when a learner (player) is stuck due to cognitive overload; by adapting the challenge if a learner (player) becomes bored or demotivated; or reinforce positive emotions to mitigate a learner's display of negative emotions within the game (Ahn et al., 2010; D'Mello et al., 2007; Fairclough, 2008). Arroyo et al. (2009) explicitly refer to Mathematics when contesting that by affective computing (programming in-play tutoring systems to recognise and respond to the affective state of a player), negative attitudes towards Mathematics can be changed.

Within the framework of this study, the observation of learners' non-verbal affective behaviours during gameplay sessions provide additional insight into learners' confidence ↔ anxiety experiences while automatizing multiplication facts through CAI. Therefore, these observations should not be regarded as psychophysiological analysis. Navarro and Karlins (2008) explicitly warns against observers wanting to attach more meaning to a specific emotion than they should. Since Ekman's (1992) first publication on the topic of interpretation of facial expressions up to the more recent publication (Ekman et al., 2013) it is repeatedly asserted that nothing could be further from the truth than singling out specific behaviours depicting specific emotions. In describing the power of facial expressions being able to depicting a single human emotion in relation to other emotions, the following quotation from Matsumoto, Hwang, Skinner and Frank (2011, p. 255) bears relevance: Facial expressions of human emotions are …

> … immediate, automatic, and unconscious reactions. These are incredible characteristics of facial expressions because learning to read them means that someone can have a bigger window into the soul of almost anyone. It is a powerful tool for investigators because facial expressions of emotion are the closest thing humans have to a universal language.

Appendix (A) extends the understanding of this framework by providing a summary from literature on the different facial expressions, gestures, body movements and postures associated with the academic emotions outlined in Figure 2.6. However, no distinct manifestations of gratitude could be found in literature. Due to the fact that Pekrun et al. (2011) omitted gratitude as a counterbalance for anger in their later studies gratitude was omitted from the framework as set out in Appendix (A).

The remainder of this chapter is devoted to findings from research literature on teaching and learning by means of digital media, specifically computers.

2.5 Computer-Assisted Instruction (CAI)

The term computer-assisted instruction dates back to the early 1970's when computers were first used for instructional purposes. Since then, the term CAI has been refined to keep up with the advances in technology. Bracey (1987) however provided a comprehensive definition of CAI that urge us to remember that CAI still remains the umbrella term, referring to all educational practices that utilizes computers and related electronic devices for instructional purposes. Bracey (1987, p.21) states that CAI refers to "drill-and-practice, tutorial, gaming or simulation activities offered either by themselves or as supplements to traditional, teacher-directed instruction."

Existing research on whether the use of computers affect academic performance has produced varied conclusions. Research indicates enhancement of learning outcomes while others conclude that computers are of questionable effectiveness. For instructional purposes in Mathematics, computers are mainly used for computerised drill-and-practice (CDP) exercises and digital game based learning (DGBL). Lin and Liu (2009) describe the difference as follows: CDP is a replication of a pen-and-paper exercise on a computer screen and the object of these so-called "games" is to win by completing a certain number of questions in the minimum amount of time. DGBL, on the other hand, has defined learning outcomes and is designed to balance the learning content with the gameplay and the ability of the player to retain and generalise that learning content to real world contexts. Seaborne and Fels (2015) adds to these characteristics of educational games by stating that voluntariness should also be taken into account – learners should be lured to the game in order to participate and learn voluntary and that learning by means of gaming should never be enforced.

2.5.1 Computerised Drill-and-Practice (CDP) in Mathematics education

CDP games are frequently used in Mathematics classrooms that have computer access as it can be introduced more readily to leaners, it can easily be integrated into the curriculum and are usually more cost-effective than DGBL (Ke, 2008; Wong & Evans, 2007).

Limited research has however been conducted on the effectiveness of CDP (Squires, 2003 cited in Ke, 2008). In comparison with Cates (2005), who explains the general effectiveness of CDP in the mathematics classroom, Duhon, House and Stinett (2012), Lehner (2008), Williams (2000) and Wong and Evans (2007) are in agreement that CDP gameplay to automatize multiplication facts could lead to improved performance. Concerning problem solving, CDP does however not show improved results over and above the pen-and paper exercises (Ghada, 2005; Leh & Jitendra, 2013). In addition to the aforementioned cognitive aspects, Smith (2010) and Ke (2008) observed affective changes as well: CDP constantly produced a more positive attitude than pen-and-paper exercises: learners exerted more effort, stayed on task for longer and even preferred computerised assistance to peer assistance. Fuchs et al*.* (2006), who included first graders in their study, not only confirmed Smith's (2010) and Ke's (2008) findings, but also stressed the important role of the teacher as mediator of computational and software skills throughout the exercise, but only when required.

2.5.2 Digital game-based learning

The assumed cognitive gains of DGBL and the respective game type that would possibly result in these assumed cognitive gains, remain a controversial issue (Vogel et al*.*, 2006). On the one hand it is argued that digital games facilitate learning by improving problem solving skills (Bottino et al*.,* 2007; O'Riley, 2016), enhance classroom instruction to ensure higher levels of retention of learning content (Blamire, 2009) and differentiate or personalise learning (Ke, 2009; O'Riley, 2016). Randall, Morris, Wetzel and Whitehill (as cited in Rodrigo, 2010) rated DGBL as superior to conventional instruction, but only on the condition that learning objectives are well-defined.

On the other hand, sceptics maintain that game-based learning does not appeal to all learners. Although it may foster higher-order thinking skills, specific content knowledge is de-emphasised (Ke, 2009). Furthermore, it often lacks connection with curricula due to the fact that teachers are not empowered to make this connection (Blamire, 2009). Hays (2005, p. 3) strongly criticises research on DGBL and refers to it as "fragmented, filled with ill-defined terms, and plagued with methodological flaws". He also doubts whether the findings of research conducted on a specific game can be generalised to other games. Ke (2009) concludes that available research is mostly unempirical, because the researchers rarely tested DGBL against other teaching methodologies. However, Hays (2005) concedes that the effectiveness of DGBL can be increased by providing timeous feedback as well as debriefing learners after the game.

Ke (2009), McClarty et al*.* (2012) and Wastiau, Kearney and Van den Berghe (2009) who conducted meta-analytical studies, are in agreement that DGBL cannot be regarded as best practice in every learning situation. According to these authors DGBL is, however, a sound alternative teaching and learning method that can supplement traditional classroom learning when mediated by the teacher. Subjects such as mathematics, science and language studies are particularly suited to gaming but can only be used if applicable to specific lesson goals as set out in the curriculum. Schaaf (2012) adds to this by emphasising that the learning goal should always incorporate the elements of play and fun to keep learners optimally engaged throughout the lesson. Choice of game is therefore crucial (O'Riley, 2016).

In their meta-analysis McClarty et al. (2012) also conclude that DGBL can generally be proclaimed effective, but suggest that researchers should turn away from the reigning '*if it promotes learning'* controversy that dominated research for over two decades and, instead, turn face towards '*how'* DGBL can facilitate and support learning.

2.5.3 Digital game-based learning (DGBL) in Mathematics education

Barnes (2005) and Barnes and Venter (2008) commented on learning strategies in Mathematics that are generally found in South African classrooms. They argued that a formal and traditional authoritarian approach has been dominating teaching and learning for a number of years. This approach afford learners little opportunity for contextual and authentic learning.

In contrast, the National Curriculum (DoBE, 2011b) promotes "active" and "critical learning" where an encouraging, active and critical approach to learning instead of rote and uncritical learning of given truths, is propagated. With regard to learning multiplication facts prescribed instructional methods called *mental mathematics,* however, heavily rely on memorisation through drill and practice with formative timed tests to monitor learners' recall of facts (DoBE, 2011b). At classroom level, the overall prognosis is even worse. Learners in the foundation phase are taught Mathematics by under-qualified teachers, resulting in an "impoverished curriculum being delivered with poor foundational competencies resulting in learners being ill prepared for mathematics in the higher grades. Learners often pass from grade to grade without passing Mathematics" (Venkat & Essien, 2011, p. 12). In a local study on mobile learning for mathematics in South Africa, Roberts and Vänskä (2011) also implicate teachers as gate-keepers excluding learners from learning mathematics through technology. Li and Ma (2010) confirm this statement by declaring that the effect of a technological enhanced mathematics curriculum is highly dependable on other impacting variables such as teacher approaches, types of games and learner characteristics.

With regard to learning basic computational facts (especially multiplication bonds), research findings confirm that DGBL is indeed an effective learning strategy: among others, studies by Faye et al. (2012), Wastiau et al. (2009) and Zhang, (2001) found DGBL to be a supplementary activity in learning multiplication facts as it not only enhances engagement and authentic learning, but also yields better retention of facts.

Apart from the barriers to integrate DGBL goals with that of a Mathematics curriculum, literature also reveals another possible argument against the implementation of DGBL: whereas educationalists blame game designers for designing 'non-integrant' games, game designers feel that by squeezing curriculum goals into their game goals, they water down games and eventually sacrifice the vital *play* element (Vendlinski, Chung, Benning & Buschang, 2011). To unite these opposing parties, commonalities between game design principles and the learning principles needs to be explored. Chapter 3 explores this issue.

2.5.4 The influence of computer-assisted Instruction (CAI) on affect

Literature findings reveal the influences of CAI on affective states of learners as displayed across subjects, but refers to attitudinal changes in terms of Mathematics in specific:

2.5.4.1 General influences

Literature, once again, makes a clear distinction between affect in CDP and DGBL. Gee (2007) argues that learners are motivated by CAI, but only when they feel a personal attachment to the goal thereof. McClarty et al*.* (2012) clarify this statement by adding that CDP only provides *external* motivation in rewarding learners for playing the game and lures them to continue practicing. The authors declare that extrinsic motivation could be successful when reinforcing low level content by means of rote memorisation. In DGBL however, where game goals and learning outcomes that involve deep understanding are closely tied together, learners are *intrinsically* motivated and rewards come from inner satisfaction of solving the challenges in the game.

By means of research conducted between 1992 and 2013, a distinct widening of research focus on CAI in terms of affective outcomes could be observed: Where older studies (68 studies prior to 1991) as analysed by Randel (1992) only concluded that learners are more *interested* in CAI than conventional teaching methods, more recent studies tend to investigate the effect of CAI on academic performance. An account of the more recent studies will be outlined in the next paragraph.

Although findings from such studies were inconclusive, Vogel et al. (2006) confirmed that CAI had been highly reliable in terms of *all attitudinal* outcomes. In Ke's (2009) meta-analysis of 89 studies, he elaborated on the nature of aforementioned attitudinal outcomes and describes it in the context of DGBL. Though DGBL may seem to facilitate *motivation* in general, he specifically outlines improved results in terms of *self-efficacy*, *affective feedback* and *persistence*. In their 2012 study, McClarty et al*.* declared that increased motivation and engagement can uncontestably be regarded as benefits of CAI over and above traditional methods, but that research should look into *what* game elements could possibly raise motivation levels. Researchers highlight aspects such as clear game goals, reinforcing feedback, increasing challenge, limited negative consequences when taking risks, opportunities to apply choice, interactivity, active agency, skills facilitation and autonomy. The studies and outcomes mentioned are non-specific in terms of subject disciplines.

Apart from motivation, a multitude of research findings on enthusiasm and improved engagement in Mathematics also came to light. To summarise, a few main recent research contributions will be outlined:

2.5.4.2 The influence of computer-assisted instruction (CAI) on affect in Mathematics education

Although heightened enthusiasm was identified in various subjects around the turn of the century, Zhang (2001) identified positive attitudinal changes that can be linked to enthusiasm in Mathematics CAI as well. In a recent, larger Malaysian study by Nordin et al*.* (2013) heightened enthusiasm was confirmed when the authors found that learners were more attracted to mathematics when digital game elements are blended into the teaching and learning process. With this knowledge about motivation and engagement in mathematics CAI, it is understandable that research also started questioning the use of CAI in alleviating mathematics anxiety.

Researchers had already been asking questions of this nature before and around the turn of the century – even when digital games were still in their inception phase. Harris (2001) ascertained that CAI can reduce Mathematics anxiety when caused by lack of confidence, negative learner attitudes, authoritarian teaching methods, teaching Mathematics in isolation without linking it to the real world, rote memorisation, speed drills and computer phobia.

Wittman et al*.* (1998) experimented with a group of 10 year old learners. A standardised measure known as Mathematics Anxiety Rating Scale - Elementary version (MARS-E) was used to separate the two groups into a high and low anxiety groups. Computerised drill against pencil-and-paper methods of learning multiplication was studied. The high anxiety group averaged the best improvement in performance. Although the apparent affective changes were only studied by means of quantitative measurements, the study resulted in sufficient empirical evidence to support the position that Mathematics anxiety may result from failure to learn basic computational skills and that by raising automaticity levels, reduction in anxiety levels could be noted in 10 year olds. CAI probably only resulted in reaching automaticity more rapidly than through conventional methods and that it still needed to be ascertained whether CAI could elicit attitudinal changes (Wittman et al., 1998). In 1999, Curtain-Phillips also started to suggest the use of CAI to alleviate Mathematics anxiety by making young learners to experience Mathematics as fun. No empirical evidence to support this statement could, however, be put forward.

The intense debate regarding the influence of CAI on academic performance reigned in research literature and could possibly explain the lack of interest in the effect of CAI on MA. However, since 2009 interest has once again been sparked and some new findings and perspectives were shared: Sun and Pyzdrowski (2009) specifically studied technology as a tool to reduce Mathematics anxiety by means of a meta-analysis of 40 prior studies. They concluded that CAI could reduce Mathematics anxiety and could be regarded as a long-term strategy as long as it is designed in such a way that it targets the internal (for example lack of cognition) as well as external (for example lack of conducive learning environment) contributing factors. These authors attribute the effectiveness of CAI to heightened engagement, working at own pace, choice in adhering to challenges, instant feedback as well as the developmentally appropriate learning environment provided by correct choice of software. Geist (2010), who reviewed literature on the same topic, contests that Mathematics anxiety could be the result of negative prior experiences related to high stress teaching methods such as timed tests. A study of which the aims and target group are (in principle) similar to this study, is that of Jansen et al. (2013). These authors studied the impact of success experiences, perceived competence and performance on Mathematics anxiety by comparing groups of learners engaging in; a) normal curricular activities and b) game-based learning with regard to addition (+) and subtraction (–) computations. Learners' level of Mathematics anxiety had been measured by a standardised rating scale, Mathematics Anxiety Scale for Children (MASC). Pre- and post-tests were conducted. The study concluded that a high success rate is a crucial feature in alleviating Mathematics anxiety as increasing success rate consistently improves math performance. Although there were no conclusive findings regarding Mathematics anxiety, findings confirmed that CAI reduces embarrassing experiences with mathematics in a conventional classroom situation.

2.6 Conclusion

While there is general consensus that academic emotions (specifically anxiety) do impact on performance in Mathematics, it does not necessarily follow that Mathematics anxiety in middle childhood will display similar characteristics to that of older learners and adults. Many gaps in literature and issues yet to be resolved could be identified: it seems as if there are limited empirical evidence, many inconclusive findings and a lack of research on the impact of CAI on affect in Mathematics education in the middle childhood years (Eden et al., 2013). Recent studies in the field not only highlighted limitations in research, but also indirectly indicated some general challenges in the field. In their meta-analysis, Li and Ma (2010) pointed out the lack of empirical evidence regarding the impact of CAI in the affective domain of Mathematics. Krinzinger et al. (2009), in conducting a longitudinal study, state that only measuring outcomes in addition (+) and subtraction (-) computations might not be the best measure in investigating the relationship between Mathematics anxiety and performance in young learners. They also urge researchers to observe physiological reactions that could be associated with MA. Furthermore, avoidance behaviours in young learners should also receive attention as it could be more reliable and valid than quantitative data obtained from Mathematics anxiety rating scales. Eden et al. (2013) elaborate on this topic and suggests that qualitative or, at least, mixed methods research design combined with longitudinal studies would yield deeper insight into the interaction of Mathematics anxiety and mathematical ability.

Due to the three overlapping disciplinary fields (Mathematics education, Affect in Mathematics education and Technology-CAI) and the three different lenses from with the research problem was viewed (affect, flow and learning), identifying a single underpinning theory that could serve as a single conceptual framework was challenging. To draft the conceptual framework for the study, the major theories in the three different disciplinary fields had been studied to identify overlapping features. The following theories could be identified respectively as a) a theory in the overlapping area between the Mathematics education and Affect in Mathematics education, b) a theory in the overlapping field between Affect in Mathematics education and Technology (CAI) and c) a theory in the overlapping field between Technology (CAI) and Mathematics education: The Control Value theory of Achievement Emotions (Pekrun et al., 2011); the GameFlow model (Sweetser & Wyeth, 2005) and the ACAT (Vandebrouck et al*.,* 2013). Deeper investigation into these models lead to the identification of the EFM model for educational game design (Song & Zhang, 2008). This model demonstrates interconnectedness between the motivation, flow experiences and environments conducive to learning and could therefore be utilized during the data analysis process.

In literature, different suggestions to the focal point in research on Mathematics anxiety in young learners have been raised. On the one hand, Ashcraft and Moore (2009) are of the opinion that more research is required on the antecedents of Mathematics anxiety while Wu et al. (2012) illustrate that more research is needed on the prevalence and manifestation of Mathematics anxiety in young learners. These authors also argue that research focusing on Mathematics anxiety in older learners diverts attention from early identification and alleviation of Mathematics anxiety. However, Eden et al. (2013) remind us that the issue of whether Mathematics anxiety in young learners is a cause or consequence of poor performance is yet to be resolved. Thus, the relation between Mathematics anxiety and performance over time still remains unspecified (Vukovic et al., 2013). According to the literature studied, the abovementioned inconsistencies could have resulted due to:

- An over-emphasis on the relationship between Mathematics anxiety and mathematics performance (the consequences of Mathematics anxiety) and the general assumption that only low ability and performance in Mathematics can be associated with Mathematics anxiety. All, but a single recent study by Wu et al. (2012) maintains the abovementioned premise.
- Inconsistent findings regarding the relationship between Mathematics anxiety and low performance frequently arose. Notably, no relations between these variables are found when learners are only tested on simple addition and subtraction facts between the ages 8 and 10. When multiplication and division (as reverse operations) as well as problem solving are added, inconsistent findings arise. From literature (as shown in sub-section 2.2.3.1), we are aware of

facts that if too much working memory capacity is consumed by calculations not yet automated, problem solving skills cannot develop. To the researcher's knowledge, no study has been undertaken in English to understand the effect on Mathematics anxiety when multiplication bonds are introduced at the age of 8 to 8½ years and expected to be automated between 10 and10½ years (as per South African Mathematics curriculum) in DGBL environments compared to conventional learning environments.

- Research findings over emphasise the relation between Mathematics anxiety and performance which results in less research on the antecedents and prevalence of Mathematics anxiety and above all, on support measures to possibly combat and eradicate Mathematics anxiety.
- No studies on the use of CAI in preventing Mathematics anxiety could be found. As afterthought to Geist (2010) study, the researcher added that by applying more developmentally appropriate and interactive approaches, high incidences of Mathematics anxiety could be prevented.
- Although research evidence affirms both CDP and DGBL as effective instructional tools in Mathematics education, research has not as yet turned face towards investigating whether CDP and DGBL are equally effective in alleviating and possibly also preventing mathematics anxiety and under what circumstances.
- Researchers mention the physiological manifestations of Mathematics anxiety as a significant data source, but as it has only been collected through quantitative methods as yet, qualitative research on this phenomenon could possibly better explain findings.
- Despite the fact that a multitude of research efforts have been devoted to precision measuring instruments (Mathematics anxiety rating scales for in younger learners) like aligning the instrument items to the developmental levels of the learners, some, but not equal efforts have been deployed to also align the Likert scale-type response format age-appropriately as well.

Chapter 3
Cognitive and affective design criteria of computer assisted learning environments

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> "As new technologies enable increasingly sophisticated game experiences, the potential for the integration of games and learning becomes even more significant"
> (Paras & Bizzocchi, 2005, p.1)

3.1 Introduction

Learning is both a cognitive and affective process (Piaget, 1950). Implicit in research literature on computer-assisted instruction (CAI) is the concept of pairing learning content with certain game characteristics to attain teaching and learning goals and also to capitalize on the power of gaming in engaging players cognitively as well as affectively (Garris, Ahlers & Driskell, 2002). While researchers have achieved consensus on educational games promoting learners' intrinsic motivation, some disagreement still exists over the nature of the game design criteria believed to elicit motivation (Dondlinger, 2007; Felicia, 2009). Seaborne and Fels (2015) argue that despite CAI's theoretical grounding in human motivation, little research that realistically and practically studied the effects of extrinsic and intrinsic motivational factors on CAI, is currently available. An abundance of literature though (as listed in table 3.1 on the next page), has been proposed to demonstrate how educational games can promote learning when players are intrinsically motivated. The transfer of acquired skills, knowledge and attitudes to settings outside the context of the game also occur more frequently in intrinsically motivated learners than knowledgeable and skilled, but unmotivated or extrinsically motivated learners (Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013). Research findings from (amongst others) the abovementioned authors clearly display that computer games do indeed influence learning by changing cognitive processes and affect motivation.

The content analysis to follow focuses on game design criteria that researchers nominated as primary determinants of motivation that also, simultaneously, promote the acquisition of learning content and skills. Table 3.1 contains a researcher-compiled synopsis of research findings on different design criteria. These elements are categorised under: *game context, situational interest, rule and goal structure, interactivity, challenge immersion and feedback.* The researcher accessed as many sources (published since the 1980's and available in English) possible. The synopsis is not intended to be exhaustive and the literature search was terminated when the same design criteria was discussed repeatedly by different authors. An analysis of the game characteristics underlying these design criteria will follow after the presentation of Table 3.1.

Table 3.1. *Educational game design criteria as revealed in literature and believed to promote learning by means of improved intrinsic motivation*

RESEARCH STUDY		**DESIGN CRITERIA**									
			SITUATIONAL INTEREST								
Researcher(s)	**Year** (over the span of 36 years)	**GAME CONTEXT**	Sensory stimuli	Curiosity	Fantasy	Mystery	**RULE and GOAL STRUCTURE**	**INTERACTIVITY**	**CHALLENGE**	**IMMERSION**	**FEEDBACK**
Malone	1981			☑	☑			☑	☑		
Lepper and Cordova	1992			☑	☑	☑			☑		
Jones	1998									☑	
Ryan and Deci	2000									☑	
Garris et al.	2002			☑	☑	☑	☑	☑	☑		
Paras and Bizzocchi	2005			☑	☑	☑	☑	☑	☑	☑	☑
Gee	2005						☑	☑	☑		
Habgood and Ainsworth	2005	☑			☑						
Denis and Jouvelot	2005	☑					☑	☑		☑	
Moreno and Mayer	2007						☑	☑			☑
Dondlinger	2007							☑	☑		
Ijsselsteijn, De Kort, Poels, Jurgelionis and Bellotti	2007						☑				
Gunter, Kenny and Vick	2007				☑			☑		☑	
Nelson and Erlandson	2007										
Ke	2008				☑		☑	☑	☑		
Song and Zhang	2008						☑		☑	☑	☑
Whitton	2010	☑		☑		☑	☑	☑	☑	☑	☑
Karimi and Lim	2010							☑		☑	
Huang, W.H, Huang, W.Y. and Tschopp.	2010							☑			☑
Sitzmann	2011			☑		☑	☑	☑			
Um, Plass, Hayward, and Homer	2012			☑		☑					
Pareto,Haake, Lindström, Sjödén and Gulz,	2012	☑									☑
Ng, Khong and Thwaites	2012			☑		☑		☑	☑		
Shin, Sutherland, Norris and Soloway	2012	☑		☑		☑	☑		☑		
Barab Barab, Pettyjohn, Gresalfi, Volk and Solomou	2012	☑									
Felicia	2012	☑		☑	☑	☑		☑		☑	☑
Liu, Li and Santhanam	2013							☑			
Sahran, Alzboon, Olimat and Al-Zboon	2013										☑
Devlin	2013			☑							
Wouters et al.	2013	☑	☑	☑		☑		☑	☑		
Deater-Deckard, Chang and Evans	2013			☑						☑	☑
Ke and Abras	2013									☑	
Plass et al.	2013		☑								
Magner, Schwonke, Aleven, Popescu and Renkl	2014			☑		☑				☑	
D' Mello et al.	2014		☑								
Mayer and Estrella	2014		☑								
Leutner	2014		☑						☑		
Mayer	2014		☑						☑		
Plass et al.	2014		☑								
Park, Plass and Brünken	2014		☑								
Arnab et al.	2015						☑				☑
Ahmad, Rahim, and Arshad	2015	☑					☑	☑	☑	☑	☑
Hamari et al.	2016								☑	☑	
Chen and Sun	2016								☑	☑	
Kronenberg	2016						☑				☑

3.2 Game Design Criteria

3.2.1 Game context

When appropriate learning content can be strategically situated within the game narrative (also referred to as plotline or storyline) and tightly paired with it throughout the game, Dondlinger (2007) and Ke (2008) believe that learners will not only experience the learning content as meaningful, but they will also be motivated to perform tasks that will enable learning as they find the game/learning activities pleasantly challenging.

Habgood and Ainsworth (2005) provide guidelines for the integration of learning content into games. Learning content must a) be delivered by means of the most fun-filled moments in play to ensure continuous flow and not interrupt the impact thereof and b) be available to be explored together with the core game mechanics[6] at the inception of gameplay. Song and Zhang (2008), however, added that the plot design should be multi-choice to provide self-choice options for players. Players will then not only be more inclined to experiment, but taking part in a self-chosen plot line will also enhance their sense of direct engagement. This will also result in continued interest in the game.

In terms of Mathematical learning, contextual relevance becomes even more significant: Bai, Pan, Hirumi and Kebritchi (2012) conclude that as opposed to classroom environments where teachers explain mathematical concepts through examples, game contexts provide a live virtual world where learners are able to understand abstract concepts by means of a visualised learning environment. Devlin (2013) contests that an intriguing game context could counteract the negative and devastating effect of rote learning methods (memorising through repetition) that tend to prevail when teaching and learning basic computational skills (for example multiplication bonds). Gameplay can provide similar repetitive practice, but learners will be intrinsically motivated as they remain focussed on the game goal, not the educational goal of memorising the bonds.

Providing an authentic and situated learning context by means of gameplay, affords greater content mastery and transfer of knowledge and skills than traditional learning through classroom teaching (Barab et al., 2012). Providing a game context as a conducive learning environment does, however, not guarantee learning; learners need to be lured to the learning environment upfront. Recent research by Kronenberg (2016) adds to this by stressing the fact that learning also takes place after the game has been played. The game should therefore be designed in such a way that it does not only lure learners to the game, but also facilitates and further induces learning opportunities on the learning goal of the game, after the game has been played.

3.2.2 Situational interest

Magner, Schwonke, Gloggler and Renkl (2012, p. 133) define situational interest as “a reaction to environmental input” and argue that all games need to elicit situational interest in order to be effective. It is, however, of particular importance in educational games as situational interest has the potential to

[6] Core game mechanics refer to the procedural mechanisms of a game that provide the essential elements required to create meaningful game activity, for example windows, control keys, icons, buttons – anything that will allow a player to interact with the game (Habgood & Ainsworth, 2005).

evolve into individual learner interest. Once situational interest is triggered, individual interest will emerge as result of personal relevance or involvement (Plass et al., 2013). In games, the user interface allows players to interact with a game through visual, auditory and tactile modes, not only by means of text. The characteristics of the interface design are therefore crucial in eliciting individual interest by means of triggering situational interest.

3.2.2.1 Sensory stimuli

Sensory stimuli refer to dynamic graphics, sound effects or any other unfamiliar stimuli that "intoxicate the senses" (Garris et al., 2002, p. 452). Succumbing to sensory stimulation is said to cause temporary acceptance of an imaginary world that pleasantly distorts perceptions not readily experienced in the ordinary world. In contributing to this topic, Mayer and Estrella (2014) warn against the use of interesting graphics without any educational role as they have found that it has no bearing on the consistent positive effect of attaining learning goals. Magner et al*.* (2012) as well as Mayer (2005) stress that although decorative graphics may trigger situational interest, it may also hinder learning as it lures the player into exploration, and therefore delays transfer of acquired knowledge and skills. Mayer (2005) found it was more pronounced in players with limited prior knowledge of the lesson content as the irrelevant sensory stimulation may result in cognitive overload. When relevant sensory stimulation is incorporated into the game design it triggers exploration of the game environment (real, virtual or imaginary) and stimulates curiosity (Whitton, 2010).

3.2.2.2 Curiosity and mystery

Discovery of the game controls, their functions and the context of the game persuades the player to understand occurrences they did not expect or that are unexplained. Garris et al*.* (2002) distinguish between sensory and cognitive curiosity. Sensory curiosity is triggered by the sensory stimulation as described above whereas cognitive curiosity refers to the desire for knowledge. *Curiosity* is therefore an individual attribute whereas *mystery* refers to information that is incomplete and or inconsistent (Malone, 1981). Mystery *induces* curiosity in an individual. According to Lepper and Cordova (1992) mystery is one of the primary drivers of learning. As individuals seek to perform at an ideal level of complexity, educational games need to provide an optimum level of cognitive curiosity – a discrepancy level that is neither perceived as too low or too high between the existing knowledge structure and the perceived knowledge to be attained during gameplay. Engeström (2000), Roth (2002), Gee (2007) and Felicia (2009) set this phenomenon equal to Vygotsky's zone of proximal development[7] (Vygotsky, 1978).

Furthermore, by embedding fantasy elements into the game context, mystery and curiosity are raised to an even higher level (Garris et al., 2002).

3.2.2.3 Fantasy

Fantasy as a game characteristic relates to the fictional game context – the make believe world underlying the game. It could on the one hand imply real locations where players' imagination create the

[7] The **zone of proximal development** (ZPD) has been defined as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p.86).

fantasy or on the other hand, entirely immersive virtual worlds filled with fantasy locations, characters, plotlines and dialogue. Gunter, Kenny and Vick (2007) argue that the integration of learning content and fantasy elements is not only a fundamental element in improving the effectiveness of educational games, but also a justifiable one as it focusses players' attention on the learning content and facilitates immersion in the game activity. More importantly, Garris et al. (2002), Habgood and Ainsworth (2005) and Ke and Abras (2013) agree that the learning content will be learnt faster if presented in a fantasy context that is of interest to the learner than in a decontextualized or uninteresting format.

Malone (1981) and Garris et al. (2002) distinguish between exogenous and endogenous fantasy elements and point to the latter as the more effective motivational tool in games. Exogenous fantasy is nothing more than a mere overlay on learning content. In both *Arithmemouse and Timez attack* (examples of multiplication games), the game characters are allowed to move through fantasy worlds of mazes by providing multiplication bond responses. The ongoing fantasy depends on the acquired skills, but not vice versa. Although the fantasies in *Arithmemouse* and *Timez attack* are unlocked by the learning content, it remains separated from the learning content and therefore external (exogenous) to it. In the case of endogenous (intrinsic) fantasy there is a continuous and mutually dependent relationship between fantasy and learning content: in *lemonade stand* for example, attaining the game goal as well as the learning goal follows an integrated approach. The skill of making lemonade is dependent on the computational skills acquired, while the computational skills cannot be acquired if the lemonade production process cannot proceed. It is this mutual dependency that caused Malone (1981) to single out endogenous fantasies as more motivational.

Although Habgood and Ainsworth (2005) agree with Malone's (1981) statement, they nevertheless conclude that endogenous fantasy cannot aspire to be a critical means of improving the effectiveness of educational games over and above the design element of immersion. Whether a player will become fully immersed in a game will depend upon the nature of the internal rule and goal structure of the game.

3.2.2.4 Gender differences

Cassell and Jenkins (1998), in studying gender differences in computer games and gameplay, already pointed to the fact that game designers missed out on half of their clientele by designing games that could only raise *situational interest* in boys. Hartmann and Klimmt (2006) specifically describe the importance of content and personality factors when explaining gender differences in CAI.

In a comprehensive study by Roig and Hurtado (2004), the abovementioned gender differences were described: the different gender groups tend to prefer games in which characters who represent their traditional gender roles and reject the opposite gender. This aspect is more pronounced in boys than girls as girls are less prejudiced against boys' games. Girls, however, prefer games to display a distinct storyline, a fantasy element and varied activities. To abovementioned list of female preferences, Hartmann and Klimmt (2006) also added pride in success and identification with attractive role models.

3.2.3 Rule and goal structure

A major challenge in educational game design is the integration of learning content into the game design in such a way that it does not interrupt the flow of the game or negatively impact on its entertainment value. In contrast to 'edutainment' games where commercialised entertainment games are randomly linked to educational content and goals, research by Ke and Abras (2013) and Arnab et al. (2015) conclude that, by prioritising the goal and rule structure design of a game, educational games will not fall prey to 'edutainment'.

Game rules are the reification of values (for example moral, scientific, educational or aesthetic) that drive a game design into a concrete framework of instructions and constraints that navigate a player through the game (Denis & Jouvelot, 2005; Whitton, 2010). Rules, however, need to display some flexibility to allow a game evolvement that depends on a players' individual playing style, selection of strategies, prior knowledge and skills of game genre and academic content. Although the rules are known beforehand how the game will play out needs to remain unpredictable (Garris et al., 2002; Seaborn & Fels, 2015; Shin et al., 2012). Rules, or rather the way they are introduced in a game, can also hinder game flow. Song and Zhang (2008) emphasise that tedious explanations of rules will consume the learner's cognitive resources and possibly prevent flow experience thus diminishing the game experience and slowing the game down altogether.

Goals are the achievement principles or outcomes of gameplay and are usually sub-divided into smaller more attainable goals that indicate the successful completion of a level. The subsequent feelings of accomplishment, apparent competence and control over the game, enhance motivation as it encourages the player on towards mastery. Depending upon the genre of the game, these intrinsic rewards are sometimes also complemented by game rewards (tokens) to serve as additional motivation (Arnab et al., 2015; Dondlinger, 2007; Gee, 2007; Whitton, 2010).

It is an uncontested fact that clear, specific and challenging goals adopted by learners during learning not only influence their motivation, but also their performance (Shin et al., 2012). Well-designed and differentiated goal and rule structures in educational games are therefore more likely to enhance motivation and performance. Within the framework of this type of goal structure, players can perceive the discrepancies between the immediate sub-goal feedback and the ultimate game goal. In their attempt to reduce this discrepancy, more attention strategies and motivation are triggered (Garris et al., 2002; Ng et al., 2012).

3.2.4 Interactivity

Players' functionality to regulate or control learning activities facilitate interactivity of the game, creating *individualised* and *differentiated* learning opportunities. Interactivity is defined as iterative two-way actions between the player and the game context in which both parties are allowed to make meaningful contributions towards the outcomes of the game (Gunter et al., 2007). Moreno and Mayer (2007) explore interactivity further and describe five types of interactivity in games: *dialoguing* (answering to questions in a game and receiving feedback in return), *controlling* (learners are allowed to make decisions that directly influence outcomes of the game), *manipulating* (for example in simulation games where learners set parameters and run simulations), *searching* (by selecting options, learners discover more content material) and *navigating* (learners move to related content areas by selecting from various content sources). Although it is generally accepted that all games are interactive, Whitton (2010) reminds us that when the player's unique actions in a game do not lead to further changes in the game itself or generate individualised feedback from the game, it cannot be considered interactive. Computer drill-and-practice (CDP) games usually operate on such premises.

The use of game *avatars* takes interactivity a step forward: avatars are virtual pedagogical characters. These instructors, coaches or learning companions vary in kind and complexity of the models used to generate and control them. They may also differ in their mode of communication, their degree of autonomy, and the way in which they are visually represented (if so) (Pareto et al., 2012). Players form a strong identity with the avatar as it is frequently self-constructed according to players' personal preferences. In this way game interaction becomes even more anonymous, and simultaneously carefree, ensuring consequence-free environments that can be explored without any implications in the real world (Faiola et al., 2013; Whitton, 2010). The game context together with potential interactivity take place within well-designed educational games and can create a safe psychosocially educational environment in which learning takes place.

3.2.5 Challenge

Where sub-section 3.2.2.2 focuses on how to raise curiosity to an optimum level, the same underlying principle (Vygotsky's zone of proximal development, 1978) applies to cognitive challenges. It suggests that players should continuously be exposed to learning activities that lie just outside of their skill level at the time (Shin et al., 2012). In such a way, players will then be motivated to improve their own previous performances. Players also need to be aware of the fact that the challenges of the game will be adjusted automatically according to their own ability at the point in time (Song & Zhang, 2008). Once the challenge (level) is met, the game produces another (slightly more difficult) learning task. Through this steady increase in challenge, learners are continuously aiming to reduce the discrepancy between own performance and ultimate learning goal – until the latter is attained (Whitton, 2010; Ng et al., 2012). Hamari et al. (2016) however advise game designers to acknowledge and keep track of learners' growing skills to ensure that their games provide adequate levels of challenge to facilitate ongoing learning in game-based learning environments.

Song and Zhang (2008) view challenge as the core motivational element of games. Once a learner is confronted with a challenge, he or she will proceed - benefitting from the self-affirmation and self-fulfilment acquired at the end of the previous challenge. Gee (2007) believes the fact that learners can be successful at a stage (level) before the ultimate goal is reached is highly motivational: he refers to it as the motivational impact of *performance* before *competence*.

Mayer and Moreno (2003), Nelson and Erlandson (2007), Leemkuil and De Jong (2012) and Leutner (2014), however, also investigated sensible cognitive load in game design as they are of the opinion that cognitive loading does not only stem from pursuing game and learning goals. The cognitive challenges within the game can easily exceed the learners' working memory capacity to process the auditory, textual or visual stimuli embedded in the game design. Cognitive overload occurs and impairs the player's ability to process the essential information vital of fulfilling the game and learning goals. Mayer and Moreno (2003) contest that an educational game designer's biggest challenge is to manage essential processing and reduce extraneous overload that stem from redundant, aesthetic design features.

3.2.6 Immersion

Gamers are able to describe the state of *immersion* in detail. However, due to diverse experiences, researchers seem to experience difficulty in putting definitions forward. The incorporation of flow in game design and subsequent GameFlow theories (refer to theoretical framework, Chapter 2, sub-section 2.3.5) during the previous decade clearly culminated in a watershed period: where pre-game flow definitions concentrated only on engagement in games, post-game flow definitions made a clear distinction between *engagement* and *immersion.*

Using the grounded theory research methodology, Brown and Cairns (2004) found that all study respondents described immersion as degrees of involvement within a game. Their definition of immersion therefore includes three progressive stages of immersion: *engagement*, *engrossment* and *total immersion*. Ermi and Mäyrä (2005), Ijsselsteijn et al. (2007), Gunter et al. (2007) and Ke and Abras (2013) all followed Brown and Cairn's notion of deeper exploration of game engagement and are all in agreement on the different degrees or stages of involvement existing - with immersion unanimously viewed as the ultimate form of engagement. These researchers are also in agreement that immersion is a pre-requisite for the ultimate attainment of game goals and that it promotes achieving learning goals as well.

3.2.6.1 Engagement

Engagement is described as the lowest form of involvement and depends on player attributes such as willingness to play, willingness to invest time and effort, and willingness to concentrate (Brown & Cairns, 2004). Gunter et al. (2007) elaborate on this by distinguishing between *affective* engagement (willingness to invest in the game emotionally), *intellectual* engagement (willingness to become cognitively involved in game challenges), *psychological* engagement (using own personality traits to respond to challenges and pursue game goals) as well as *physical* engagement (willingness to participate on a kinaesthetic level). They also found that individual differences in engagement stages are the norm across various game stimuli (for example auditory and visual), across a variety of settings (home, school or play) and that engagement is predicative of attaining cognitive goals in games.

Debating engagement in mathematics games, Deater-Deckard, Chang and Evans (2013) emphasise affective engagement as equally important as cognitive engagement and recorded the following indictors as measurement of affective engagement: enjoyment in gaining mathematical knowledge and skills; curiosity when exploring new mathematical concepts and feeling satisfied when attaining learning goals of the game that were initially perceived as "tough" or "boring". Hamari et al. (2016) emphasise that a balance between a game's challenge and a player's skill leads to further engagement and ultimately engrossment and immersion as described in the next two sub-sections 3.2.6.2 and 3.2.6.3.

3.2.6.2 Engrossment

Whereas engagement depends on conscious choices made by the player, *engrossment* eradicates all negative feelings, such as feelings of guilt that the player may have due to ineffective time management within the game. All design features are now combined into a coherent, pleasurable experience during which players become emotionally involved in the game. They are even able to recall feelings of being emotionally drained when play has ended. Players become less aware of their physical environment and self-awareness fades (Brown & Cairns, 2004).

3.2.6.3 Total immersion

In this stage, players detach themselves from reality and experiencing the game is all that matters (Brown & Cairns, 2004). Sweetser and Wyeth (2005), when designing game flow models, distinguished between flow and total immersion. They found it to be two sides of the very same coin and described it as "deep but effortless involvement, which can often result in loss of concern for self, everyday life and an altered sense of time" (Sweetser & Wyeth, 2005, p. 10).

Ermi and Mäyrä (2005) identify three immersion categories: *sensory* immersion, *challenged based* immersion and *imaginative* immersion. The design criteria contributing towards immersion can clearly be located when attending to these categories. Sensory immersion refers to the multi-sensory stimuli described in sub-section 3.2.2.1 and the perceptual impact thereof on the player. Challenged based immersion relates to the balanced cognitive effort to meet the game challenges and reach a state of flow. Attention to challenge as a design element as described in sub-section 3.2.5 is indicative of whether total immersion will be reached. Finally, imaginative immersion refers to optimal engagement with the imaginary game world. All the design criteria coordinating situational interest (sub-section 3.2.2) and the game context (sub-section 3.2.1) contribute towards rich experiences that can ultimately result in total immersion. Recent research by Chen and Sun (2016) adds to the abovementioned pre-requisites for immersion by confirming that once a perfect balance between a player's skill level and game challenge is reached, flow is inevitable; thus enhancing the chances of total immersion.

In Brown and Cairn's (2004) study, respondents attributed total immersion first and foremost to specific design features: empathy with in-game characters, the atmosphere created by the graphics, the plot and sound effects. Furthermore, Gunter et al. (2007) also stress that although both interactivity and engagement are pre-requisites for immersion, engagement does not necessarily guarantee immersion, nor does interaction guarantee engagement. To enter iterative game cycles, deeper immersion is required. One of the aspects enabling players to reach states of deeper immersion is the positive in-game feedback received.

3.2.7 Feedback

Through in-game feedback players are able to track their game progress and reflect on past performances. Although players realise that they are incompetent, the nature of feedback they receive allows them to perform well and continue playing (Arnab et al., 2015; Gee, 2007; Shin et al., 2012; Whitton, 2010). Feedback may however elicit different affects among players and therefore Song and Zhang (2008) suggest that the frequency, accuracy and cue mechanism design should be carefully considered. Feedback can be perceived as an umbrella construct that incorporates numerous design details of which reflection, transfer and automaticity will be discussed.

Reflection remains a challenging issue in game design and according to Paras and Bizzocchi (2005) and Ke (2008) the topic has not been researched in depth yet. Game designers are cautious about reflection interrupting game flow and derailing game goals (Gee, 2007; Ke, 2008) while educationists regard it as essential. Educationists argue that no learning is fully realised until learners are empowered to reflect on events that took place during the gaming experience and meta-cognitive awareness surfaces (Paras & Bizzocchi, 2005; Shin et al., 2012; Whitton, 2010).

Ke (2008) refers to three types of reflection mechanisms from literature: *informative feedback*, *reflection assignments* and *cognitive modelling tools*. Informative feedback is an individualised error analysis and remedial intervention between game cycles that facilitate knowledge and skills transfer. Singling out arithmetic skills, Huang et al. (2013) propose an in-game diagnostic mechanism whereby the game system can infer the learner's thinking patterns based on answers provided. When incorrect answers are submitted, the system will provide indicative feedback, prompting strategies to correct the answer. Should a learner still fail, the system will then provide the correct answer accompanied by remedial intervention. The multiplication game, *Timez attack*, utilises a similar informative feedback system.

Reflection assignments are the explicit revisiting of learning goals, presented with in-game incentives or rewards as an attempt to preserve game flow. Cognitive modelling tools, on the other hand, refer to design criteria that interrupt the game by continuously summarising the essence of the learning content, enabling learners to distinguish between vital and incidental or trivial information provided by the game.

To pave the way towards finding a suitable solution to the dilemma, Paras and Bizzocchi (2005) suggest endogenous implementation of reflection. The reflection phase needs to be designed in such a way that learners perceive it as one of the many in-game goals that need to be attained. By means of this design, game flow will seemingly be uninterrupted. Ke (2008) is, however, of the opinion that further research is required to maintain the equilibrium between feedback and reflection as instructional support on one side, and preserving the power of gameplay on the other.

3.2.7.1 Transfer

Paras and Bizzocchi (2005) and Felicia (2012) contest that the attainment of cognitive game goals, will stay confined to the game context if the game is not temporarily interrupted by feedback sessions that facilitate transfer of newly attained knowledge and skills. Gunter et al, (2007) are also concerned that the transfer of acquired knowledge and skills may not necessarily take place during a once-off gameplay and that repetitive gameplay sessions may be necessary to facilitate the transfer of acquired knowledge and skills. Shin et al. (2012) also state that through repetitive use and practice acquired skills become available for use outside the game context.

The motivation to return to the game repetitively therefore needs to be carefully planned and designed. Felicia (2012) concludes that learners need to feel cognitively empowered – even after an initial gameplay session. They need to revisit their own pre-game perceptions of the learning content being either too abstract or too difficult. The self-efficacy and self-confidence that may develop from this endeavour will motivate learners to return to the game….repeatedly.

3.2.7.2 Automaticity

Automatisation (in the context of arithmetic) is a fast, fairly effortless process that is not limited by a learner's short-term memory capacity as it is not under direct control of the learner and results in well-developed computational skills. Automaticity typically develops when learners are repeatedly stimulated (Schneider & Fisk, 1983). It can be inferred that if learners are repeatedly motivated to return to a game in which skills that should preferably be automated (for example basic computations) are presented, automaticity could be attained. Jones (1998) explains this strategy as follows: initial arithmetic practicing (by means of gameplay) requires reflective cognition – comprehension, analyses, synthesis and evaluation. With repeated practice (also referred to as 'drill') reflective cognition is no longer required; the learner is able to react to the content effortlessly and efficiently, almost instinctively.

Whitton (2010) points out that although adventure games are not strictly as competitive as timed computer drill-and-practice games, it can be more beneficial when skills need to be automated. Plass et al. (2013), however, contest this stating that in developing computational fluency, preference is given to competitive modes of gameplay over and above individual or collaborative modes. They argue that competitive games could increase situational interest and enjoyment.

It nevertheless stands to reason that feedback remains a vital design element in educational games: recognition of attained knowledge and/or skills as well as affective feedback is vital to achieving sound game goals as well as learning goals (Huang et al., 2013). Discrepant research findings, as outlined in the previous paragraph, however, seemed to motivate research into *affective* design criteria of computer games and during the first years of this decade produced a new research field called *emotional design.* Although emotional design research is focused on *situational interest* research, it is still in its inception stage. It is (within the context of this research) also desirable to put effort into affective constructs that might (in terms of motivational value) enhance the effectiveness of other design criteria.

3.2.8 Emotional Design

Leutner (2014) observes that affective aspects such as emotion and motivation have a long standing tradition in research on computer assisted instruction (CAI). Since Moreno's Cognitive and Affective Theory of Learning with Multimedia (CATLM) was introduced in 2006, it provided a framework for future research (Moreno & Mayer, 2007). Since 2013 it has been against this framework, that research teams under the leadership of Plass, Mayer, Park, de 'Mello and Um began providing valuable insights on the affective design factors that are said to influence CAI. Ng et al. (2012) provide a rationale for this renewed research focus by contesting that with the rapid growth of technology and the competitiveness of the gaming industry, game designers began incorporating design criteria that would provide the same user experience to all players, despite individual differences with respect to player motivation and prior gaming skills or experience. Drawing inferences about players' emotional states to understand levels of engagement and motivation became their prime research focus.

What is emotional design? It is a design strategy that enhances the level of personification or visual appeal of essential design criteria, which in turn leads to improved learning outcomes by increasing the cognitive engagement of the learner (Magner et al., 2014; Mayer & Estrella, 2014; Park et al., 2014; Um et al., 2012). Plass, Heidig, Hayward, Homer and Um (2014) expand this definition by adding that negative emotions such as anxiety and anger may also have activating motivational properties. Anxiety may, for example reduce intrinsic motivation, but in order to avoid failure, it may simultaneously be regarded as an emotion that increases extrinsic motivation. The research team, however, emphasised that the relation between positive deactivating emotions (for example relaxation) and negative activating emotions (for example anger and anxiety) is complex and needs to be investigated more in terms of influencing learning outcomes in CAI learning environments.

The abovementioned research teams applied experimental research designs and through induced alterations to design features assumed to influence emotion and motivation results in terms of differences in cognitive processing. It is said that these cognitive processing differences, in turn, lead to differences in learning outcomes (Leutner, 2014).

Um et al. (2012), Plass et al. (2014), Park et al. (2014) and Magner et al. (2014) raised awareness of a different use of emotional design. These researchers studied the development of appealing graphical design criteria that were apparently downplayed as the *seductive detail* effect or *coherence principle* in previous research by Mayer and Moreno (2003). The abovementioned research teams concluded that a joint emotional effect exists between the use of round, face-like shapes of instructional agents (for example avatars) and the use of warm interface colours. Their altered emotional designs resulted in improved transfer of knowledge and skills as well as better motivation to learning. Um et al. (2012) attribute the learning gains to positive emotions facilitating processing abilities of both working and long term memory. Plass et al. (2014), however, insist that these findings are preliminary and that more research is required as gender differences in brain responses to visual stimuli as well as cultural factors in affective meanings of colour could have influenced research results.

D'Mello, Lehman, Pekrun and Graesser (2014) contributed towards the research on emotional design by investigating the effect of induced cognitive confusion that may lead to deeper inquiry into learning content and extended mental effort. They found that confusion as an affective state can be regarded as a motivational design fostering cognitive processing – but only on the condition that extraneous processing (for example focussing on reward systems of the game) does not cause cognitive overload that distracts the learner from the essential processing. The research team concluded that inducing cognitive disequilibrium may be beneficial in terms of learning, but the method in which confusion can be induced, regulated and resolved within games still needs to be studied. Despite these initial research findings that provide a valuable step in directing emotion design research, studies on affective constructs that moderate the effectiveness of CAI design are still in its inception phase.

3.2.9 Learning Principles: Conventional Classroom Instruction versus Computer-Assisted Instruction

Sound pedagogic practices are underpinned by universal core principles of learning – irrespective of the learning environment (conventional or assisted by digital media). Table 3.2 shows the design criteria as underwritten by Paras and Bizzocchi (2005), Houser and DeLoach (1998) and Sale (2006).

The first column of Table 3.2 reveals Paras and Bizzocchi's (2005) seven design criteria of effective conventional learning environments design as proposed by Houser and DeLoach (1998) to be an appropriate guideline for designing educational games. Sale (2006) then formulated ten design criteria for learning environments that provide an empirically based framework from which teachers can effectively plan learning experiences. These design criteria are also replicated in the first column of Table

3.2 and are indicated by means of b) to distinguish it from that of Paras and Bizzocchi which are indicated by means of a).

To complete this synergy Table 3.2 merges the gameflow criteria proposed by Sweetser and Wyeth (2005) with the design criteria of both conventional learning and digital learning.

Table 3.2. *Learning environments: design criteria*

LEARNING ENVIRONMENTS: DESIGN CRITERIA		
CONVENTIONAL CLASSROOM INSTRUCTION a) as iterated by Houser and DeLoach, 1998 *b) as iterated by Sale, 2006*	**COMPUTER-ASSISTED INSTRUCTION** (as analysed in different sub-sections of this chapter)	**GAME FLOW CRITERIA** (Sweetser & Wyeth, 2005) (displaying the synergy between design criteria presented in both conventional and computer assisted learning environments)
a) Provide a high intensity of interaction and feedback. *b) Learner competence is promoted through active and experiential learning*	**INTERACTIVITY** (sub-section 3.2.4)	Will players be able to follow game instructions without having to read a manual? Does the game provide help without having to exit the gameplay level? Will the players have a sense of control over characters/avatars, interaction and movements in the game? Will they be able to feel that their actions can change the game world for the better?
a) Have specific goals and established procedures. *b)Learning goals, objectives and expectations are clearly communicated* *b) Content is organised around key concepts and principles that are fundamental to understanding the key structures of a subject* *b) Learning design takes the working of memory systems into account*	**GOAL & RULE STRUCTURE** (sub-section 3.2.3)	Are the overriding game rules clear and presented early in the game? Are the game rules, interfaces and mechanics easy to learn and use? Are the intermediate game level goals presented timeously and clearly? Are players free to use own strategies and only be prompted by the game if they should tend to fail in applying own strategy?
a) Motivate learners *b) Learners' prior knowledge is activated and connected to new learning* *b) Motivation and attention strategies are incorporated into learning designs*	**SITUATIONAL INTEREST** (sub-section 3.2.2)	Does the game provide a lot of sensory stimuli from different sources? Will players find the stimuli worth attending to? Will the game quickly grab player's attention and maintain their focus throughout the game? Will the players be taught how to play the game by means of tutorials that feel like playing the game?

LEARNING ENVIRONMENTS: DESIGN CRITERIA		
CONVENTIONAL CLASSROOM INSTRUCTION a) as iterated by Houser and DeLoach, 1998 *b)as iterated by Sale, 2006*	**COMPUTER-ASSISTED INSTRUCTION** (as analysed in different sub-sections of this chapter)	**GAME FLOW CRITERIA** (Sweetser & Wyeth, 2005) (displaying the synergy between design criteria presented in both conventional and computer assisted learning environments)
a) Provide a continual feeling of challenge that is neither so difficult as to create a sense of hopelessness and frustration, nor so easy as to produce boredom *b) Self-directed learning is encouraged through facilitating the development of good thinking*	**CHALLENGE** (sub-section 3.2.5)	Does the game have a high workload, but still appropriate to players' perceptual, cognitive and memory limits? Will players be burdened by tasks that they do not regard as important? Do the game challenges match players' skill levels? Does it cater for individual differences and preferences? Does game challenges rise per level? Are the difficulty levels proportionate to increased skill levels of the player? Does the game prevent players from making mistakes that are detrimental to the gameplay?
a) Provide a sense of direct engagement, producing the feeling of directly experiencing the environment, directly working on the task. *b) A psychological climate which is positive, success orientated and promotes self-esteem is created*	**GAME CONTEXT** (sub-section 3.2.1)	Are there any game elements distracting learners from the tasks they should concentrate on? Will learning in the game be boring or part of the fun? Will players become emotionally attached to the game?
a) Provide appropriate tools that fit the user and task so well that he can get aid and do not distract. *b) Assessment practices are integrated into the learning design to promote desired learning outcomes and provide quality feedback*	**FEEDBACK** (sub-section 3.2.7)	Do players receive in-game feedback on their progress towards both game and learning goals? Do players receive immediate feedback on actions taken in the game? Is the game score or status revealed throughout the game? Will the game reward players appropriately for their effort and skill development? When errors are made, does the game provide feedback and support towards correcting errors?
a) Avoid distractions and disruptions that intervene and destroy the subjective experience. *b) Instructional methods and presentation mediums engage the range of human senses*	**IMMERSION** (sub-section 3.2.6)	Do players become less aware of their surroundings when playing a game? Do players become less worried about everyday life or the self when playing the game? Do players experience an altered sense of time when playing? Will players also be able to feel viscerally involved in the game, not only cognitively?

3.3 Conclusion

Research into the design criteria of computer-assisted instruction needs to follow a pace set by a rapidly expanding world of technology. What could be considered as pedagogically founded design principles today, could tomorrow be a historical account. Limitations to this content analysis on design criteria were therefore encountered: Very few studies singled out game design criteria that positively influenced learning through inducing intrinsic motivation. Even fewer studies attempted to identify to what extent these game design criteria could influence learning. Studies on the nature of game design criteria apparently produced overlapping results that are overshadowed by the fact that game design criteria are characterised and categorised differently by various researchers – they use different approaches and terminology to describe similar game dimensions.

Recent research into the different existing design frameworks for educational games analysed the frameworks against already set criteria for effective educational games (Ahmad et al., 2015). These authors concluded that the differences in the quality of the products (educational games) do not lie in the type or effectiveness of each design element, but in the *relationships* between the different design criteria. Assessing the effectivity of an educational game, lies in… "establishing how one element collaborates with other elements to ensure the effectiveness of the game. Without these relationships, effectiveness of the design cannot be measured" (Ahmad et al., 2015, p. 25).

Despite the aforementioned, it stands to reason that well-designed educational games can indeed be regarded as pedagogically sound learning environments promoting not only cognitive, but also affective learning behaviours (Felicia, 2012; Paras & Bizzocchi, 2005). O'Riley (2016, p.23) argues that "Digital games provide a space where learning through play can exist". Games and learning could therefore truly account for the two sides of the very same coin.

In the next chapter, Chapter 4, the qualitative research design of the first research phase (Phase 1) of the study will be discussed.

Chapter 4
The Qualitative Research Design: Phase 1

4.1 Introduction and Orientation to the Research Design

Apart from the different theoretical frameworks underlying this study, Chapter 2 also covered research findings on Mathematics anxiety and Computer-assisted instruction (CAI) in both Computer Drill-and-Practice (CDP) environments and Digital Game-Based Learning (DGBL) environments. Chapter 3 followed by outlining the design criteria that form the bedrock of CAI as revealed through literature. The constructs of academic emotions and affective computing are also explored in Chapter 3.

In this chapter (Chapter 4) the qualitative research design of the first research phase (Phase 1) of the study will be discussed. As the study scrutinised a particular learning strategy (CAI) in Mathematics Education, it can be described as a collective case study conducted from an interpretivist perspective: the study strives towards understanding how participants (learners) experience Mathematics anxiety in learning environment where they have to make meaning of multiplication facts.

The research was conducted in two consecutive phases since the study necessitated a preparation phase (Phase 1) during which the research instruments for investigating abovementioned phenomenon, had to be prepared before data directly pertaining to answering the main research question could be collected during Phase 2. Phase 1 (preparation phase) consisted of two parallel processes that encompass Phase 1A and Phase 1B. Phase 1A (described in Chapter 4a) consists of the adaptation, piloting and re-adaptation of the standardised SEMA instrument[8] while Phase 1B (described in Chapter 4b) focusses on analysing literature on CAI games to provide a broad basis of understanding of the design criteria thereof to ultimately enable the selection of appropriate data collection instruments (CAI-games) used in Phase 2. Phase 2 (set out in Chapter 5) then focusses on describing Grade 4 learners' anxiety experiences in CAI environments by analysing data obtained by means of interviews, gameplay and individual post-gameplay interviews. To orientate the reader, a discussion of the assumptions and paradigmatic perspective of the researcher follows first. Thereafter, the respective research designs for both Phases 1A and 1B will be outlined.

4.1.1 Researcher's assumptions

Leedy and Ormrod (2010, p.5) stress that assumptions are certain "self-evident truths" that serve as the bedrock upon which an entire study is based. With respect to this study, the researcher assumed that automaticity in terms of the recall of multiplication facts is one of the fundamental and universal mathematical skills. The researcher also assumed that the learners as research respondents or participants have attained the minimum curriculum requirements up to the previous grade (Grade 3), with specific reference to the basic mathematics concept of repeated addition that constitutes a solid foundation upon which multiplication skills can be acquired. As a final assumption, the researcher affirms

[8] The Scale for Early Math Anxiety (Wu et al., 2012. Refer to Chapter 2, sub-section 2.4.3.6 for a discussion of this Mathematics anxiety rating scale. This research instrument will henceforward be referred to as the SEMA instrument).

that (as far as possible and up to the point of participation) none of the research respondents or participants[9] were presented with any intrinsic barrier (other than the possibility of Mathematics anxiety) that could possibly affect the way in which the respondents or participants would react affectively to mathematical content and/or working with technology. The theoretical assumptions that follow (in section 4.1.2) were based on the abovementioned personal assumptions.

4.1.2 Theoretical assumptions

Engeström's Activity theory (Engeström & Sannino, 2010) offers a set of perspectives on human activity and a set of concepts for describing the activity. According to Nardi (1996) and Dondlinger (2007), computers can be looked upon as artefacts (mediating tools). Bishop (1988) and Radford (2008) furthermore concluded that mathematics do arise from cultural history. Activity theory therefore sufficed as an over-arching theoretical foundation for describing CAI in Mathematics (LaCroix, 2012; Vandebrouck et al*.,* 2013). Vandebrouck et al*.*'s (2013) ACAT furthermore proposes a framework for investigating teaching and learning in *Mathematics* by interacting with *computers* as virtual manipulatives in social settings. Refer to chapter 2 (sub-section 2.3.2) where the functions of the *subject, object,* an *artefact* and *the subject's motives* are described in the context of the current study.

4.1.3 Philosophical aspirations of the researcher

Conducted from an interpretivist perspective the researcher aspires towards understanding how participants (learners) experience Mathematics anxiety in learning environments where they have to make meaning of multiplication facts through a series of different CAI strategies as opposed to conventional strategies in non-computer assisted, conventional classroom teaching and learning. The researcher, being first and foremost a teacher, continually involves herself with learners, teachers and parents/caregivers who, together, form a specific social community that not only constructs meaning with the aim of enabling all role-players to strive towards a common goal, but also a community acting in unison to accomplish this goal. From this perspective, and in alignment with Millar (2004), the researcher asserts that learning is a social endeavour and that knowledge and skills (automatisation of multiplication bonds) is dynamically constructed through the relationship amongst individuals, as well as (or without) computer-assisted learning environment(s). The paradigmatic lens through which the research problem was viewed will henceforward be described.

4.1.4 Paradigmatic lens

The researcher ontologically states that a single view on reality does not exist and that all individuals have their own unique interpretation of reality. This pragmatic ontology does not negate the objective truths underlying the positivist approaches, but prefers to hold an interpretive view of individuals experiencing meaning making within their natural settings. Following the perspective of Denzin and Lincoln (2011), the researcher aims to understand the nature of such a reality, namely the

[9] In qualitative studies, research 'participant' is generally the accepted term relating to research contributors. The researcher, however, wishes to agree with Jansen (2010), Roller (2014) and Roller (2015) in viewing the survey contributors in qualitative studies 'respondents' and not as participants. As both types of research contributors are used in this study, 'respondents' are used to describe the contributors to surveys (pilot project respondents and teachers as well as learners who completed questionnaires) in the first research phase. The remaining research contributors (Phase 2) are referred to as 'participants' as they contributed by means of a focus group interview, gameplay sessions and individual interviews.

anxiety↔confidence experiences occurring when the skill of automaticity regarding multiplication facts is acquired.

Qualitative research is "a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings and memos to self … qualitative researchers study things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them" (Denzin & Lincoln, 2011:3).

By following a qualitative approach to the research problem, the researcher investigated Grade 4 learners' *confidence* ↔ *anxiety*[10] experiences in CDP and DGBL environments while automatising multiplication facts. In this study, the researcher not only observed *tools/artefacts* (CAI) as described in sub-section 4.3, but also *people* (learners' affective behaviours while acquiring automatisation with respect to multiplication skills). Due to these different realities, necessitating different approaches in terms of method, process and execution, the research was conducted in two phases (Phase 1 and 2). Phase 1 needs to be viewed as the preparation phase for the research conducted during Phase 2.

4.2 Introducing the Research Design of Phases 1A and 1B

As the research methodology of the different phases and sub-phases (as described in sub-section 4.1) differed in terms of purpose, data format and methods of analysis, this chapter will describe the respective research designs of Phases 1A and 1B. The research design of Phase 2 will be set out in Chapter 5. Table 4.1 orientates the reader by stating the main research activity of each sub-phase (Phases 1A and 1B), the relevant research sub-questions, the data collection and data analysis procedures. The table furthermore outlines the purpose of the data collection and analysis procedures and points the reader to the chapter in which the research results will be presented.

[10] Valence, as used in psychology, when referring to emotions, means the intrinsic attractiveness (positive valence) or averseness (negative valence) of an event, object, or situation (Frijda, 1986). Throughout this study the symbol (↔) will be used to express abovementioned valence relationship between positive and negative valence. The reader is referred back to the literature review (Chapter 2, sub-section 2.4.2 and Figure 2.5) for a detailed exposition of this construct.

Table 4.1. *Overview of research design: Phase 1*

RESEARCH PHASE	Main research activity	Method of data collection	Purpose	Analysis procedure	Chapter in which findings are revealed
PHASE 1A	Preparation for Phase 2 by answering to the first research sub-question:	Adaptation of the SEMA instrument and pilot project	To adapt and compile focus group interview questions and open-ended prompts in the South African context	Content analysis of SEMA to contextualize to South African context.	
	<u>*Research sub-question 1*</u>*: What is the conceptual value of adapting the SEMA instrument with regard to the research design of the study?*	Re-adaptation of SEMA instrument.		Content Analysis of the pilot project: respondents' responses to trialled questionnaire items	4
PHASE 1B	Preparation for Phase 2 by answering to research sub-questions 2 an 3:	Literature study on CAI game design criteria	To identify the criteria for CDP and DBGL environments	Content analysis: tabulation of game design criteria to align with game design criteria of traditional (classroom) learning environments	
	<u>*Research sub-question 2*</u>*: What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?*	Teacher/learner questionnaires	To identify suitable games for gameplay sessions in Phase 2	Qualitative analysis (categorisation and interpretation of common themes through a-priori coding and inductive reasoning)	6
	<u>*Research sub-question 3*</u>*: Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?*				

To enhance understanding of the parallel research processes of Phases 1A and 1B, Figure 4.1 visually displays the situation analysis, criteria identification and instrument adaptation described in this sub-section. This figure will be followed by a detailed description of the research design of Phase 1A.

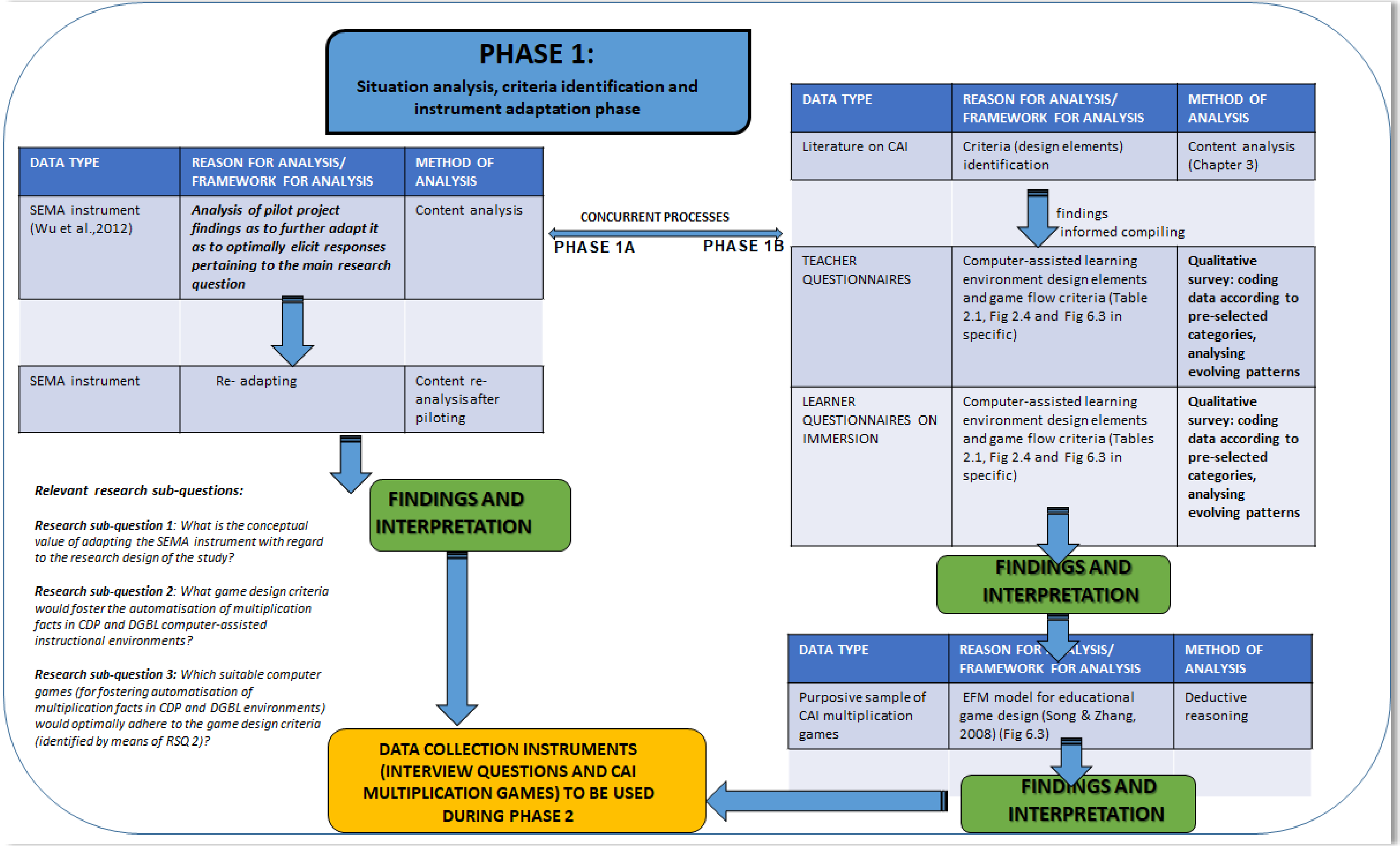


Figure 4.1. Phase 1: Situation analysis, criteria identification and instrument adaptation (Take cognisance of the two parallel processes, Phase 1A and Phase 1B that took place concurrently).

4.3 Research Design: Phase 1A

The following two sub-sections (4.3.1 and 4.3.2) orientate the reader towards the research design of Phase 1A. The data collection instruments and procedures as well as the data analysis procedures applied will be outlined in sub-sections 4.3.3 and 4.3.4, respectively.

4.3.1 Adapting the SEMA instrument for research sub-question 1 (Phase 1A)

To enhance understanding learners' anxiety experiences in *conventional learning environments*, the researcher utilised a standardised measuring instrument as the starting point of describing of a possible manifestation of Mathematics anxiety in this learning environment. From all possible measuring instruments revealed in the literature review (Chapter 2, sub-section 2.4.3.6), the SEMA instrument was found to be adaptable. The SEMA instrument could and was adapted as it consisted of response items to be used in quantitative studies and therefore ineffective as focus group interview questions to be used in this qualitative study (during Phase 2). After adaptation, the adapted items were piloted. The piloting resulted in further adaptation before a final draft could be compiled to be used in Phase 2 of the study in order to collect verbal (interview) data. Analysis of the interview data on Mathematics anxiety in conventional learning environments provided a lens through which the Mathematics anxiety experiences in CAI environments could be viewed. Phase 1A therefore sets out a comprehensive, sequential approach to answer *only* to the first secondary research question:

Research sub-question 1: What is the conceptual value of adapting the SEMA instrument with regards to the research design of the study?

4.3.2 Context of research site, population, sampling and respondents (Phase 1A)

Data were collected at a single research site - a suburban ordinary public primary school situated in one of the districts of the Gauteng Department of Education and was selected by means of convenience sampling - the researcher being a permanent staff member. The school is classified as a parallel (Afrikaans and English) medium school and had approximately 1320 learners in 2014. The Grade 4 group comprised of five English classes and one Afrikaans class with a total of approximately 180 learners. According to the 2014 annual departmental school survey (GDE, 2013; 2014), the learners' parents/caregivers reside or are employed in the school's feeder area and are mostly socio-economic middle income households. In the same report the ethnic diversity was recorded as approximately 780 white learners (59,09%); approximately 420 black learners (31,8%) and coloured, Indian and other ethnic groups represented approximately 120 learners (9,09%) (GDE, 2014).

Sampling of respondents for the pilot project (Phase 1A) followed the following procedures: Nieuwenhuis (2007) describes criterion sampling as planning to inviting learners displaying typical characteristics that would most likely lead to better insight into the research topic. Six learners were invited according to criteria outlined in the remainder of this paragraph. The sample of six (n=6) respondents were selected from the population of 120 (N=120) (total number of Grade 4 learners in English classes at the research site) and invited to take part in the initial part of the study (trialling the adapted SEMA instrument, being referred to as: pilot project) (Onwuegbuzie & Collins, 2007). These respondents were invited from the five Grade 4 classes with English as the medium of instruction at the research site and not from the single class with Afrikaans as medium of instruction. This constitutes the first criteria. Other criteria were chronological age within close contingency and same gender. To increase the internal validity of the findings of the overall study, learners were invited according to the abovementioned criteria in order to limit possible confounding variables (Leedy & Ormrod, 2010). The following aspects were considered to be possible confounding variables:

Gender: *Either* boys *or* girls could be identified: Research findings by Stuart (2000), Zan et al. (2006) and Kim and Chang (2010) and indicated gender differences in Mathematics anxiety experiences. In a recent literature review on Mathematics anxiety, Dowker, Sarkar and Looi (2016) came to the conclusion that although both genders could be afforded similar exposure to Mathematics teaching and learning opportunities, females still tend to rate themselves lower regarding mathematical performance and could therefore be more susceptible to anxiety experiences when in Mathematics teaching and learning situations. Due to this possibility, a homogenous gender sample was preferred.

Developmental stage: Respondents were preferred to be of more or less the same chronological age – born as closely together as possible – as it could possibly indicate a possible similar developmental stage[11] in which the respondents are able to mentally process mathematical concepts and acquire multiplication skills at approximately the same cognitive level (Doherty & Hughes, 2009; Engelbrecht, 2012; Piaget, 1950; Van Zyl, 2011).

Felicia (2009) – in the context of visual and/or auditory instructions in CAI environments - emphasised that learners' language ability could influence the manner in which they would react to verbal instructions. Respondents' language proficiency could therefore also influence the quality of the data to be collected and a similar understanding of the language level used in the adapted SEMA items would be preferable. The language proficiency (as rated by means of the 2013 ANA assessment outcomes in English Home Language) were therefore applied as a selection criteria. (Doringkloof Primary, 2013).

The criterion sample of six (n=6) respondents could be identified through studying school records as mentioned in the previous paragraph. Informed consent was obtained from the relevant education department, the school governing body and the school management team. These six Grade 4 girls were invited to take part in the trialling of the adapted SEMA instrument. Figure 4.2 illustrates the sampling process described in this sub-section.

[11] 'Developmental stage' is a term used in the field of developmental psychology referring to distinct and separate stages at which different kinds of human behaviour occur. The development of certain abilities in each stage, such as specific emotions or ways of thinking, display a definite starting and ending point. There is, however, no exact time at which an ability suddenly appears or disappears (Piaget, 1950).

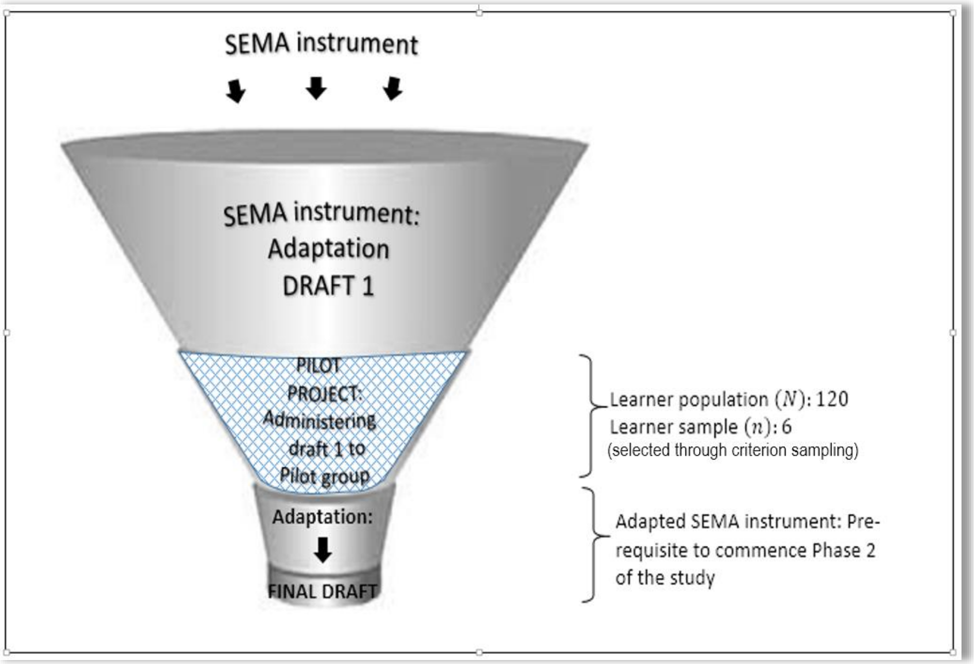


Figure 4.2. Phase 1A: Sampling procedures used during pilot project

4.3.3 Data collection instruments and data collection procedures (Phase 1A)

To address the first research sub-question, the SEMA instrument (Scale for Early Math Anxiety - Wu et al., 2012, Appendix B) was adapted in preparation for a data collection instrument. This data collection instrument was used to collect data during a focus group interview in Phase 2. Through analysing the data improved understanding of participants' Mathematics anxiety experiences during automatisation of multiplication facts in conventional learning environments could be attained. The reasons for adapting Wu et al.'s (2012) SEMA instrument were fourfold:

Firstly, Wu et al. (2012) used a 5-point Likert scale to indicate responses coupled with a graded picture series of 'non-anxious' to 'very very anxious' faces. The rating scale used in the adapted SEMA instrument (Table 4.2) is the researcher's self-illustrated and adapted version of Baker's (2005) faces for young children's rating scales as cited in Cravero, Fanciullo and Baird (2013). These faces were used in the handheld artefact (Figure 4.3) during the pilot project and the focus group interview in the second research phase.

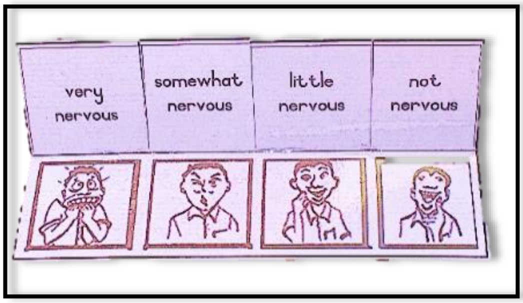


Figure 4.3. Artefact to assist research respondents in responding to the adapted SEMA items (adapted version of Baker's (2005) faces as cited in Cravero et al., 2013)

The option of "very-very nervous" on the SEMA's rating scale was abandoned in the first place due to the developmental levels of the particular target group in this study being significantly higher than the developmental levels of the learners Wu et al. (2012) piloted the SEMA on. Since the 5-point Likert scale could be manipulated by older learners by frequently selecting the third (middle) option, it provided a second reason why the option of ‘very-very nervous” was abandoned. The researcher designed an artefact to assist learners in using abovementioned 4-point scale to their responses to the adapted SEMA items.

Secondly, the instrument was designed and intended for learners from the United States as the practice question of the instrument required naming the president of the United States and using the currency (pennies and dimes). These concepts are not within the frame of reference of South African Grade 4 learners and therefore had to be contextualised in terms of South African names and currency.

Thirdly, the SEMA statements involved a variety of concepts from the first content area (Numbers and Operations) from the South African Mathematics curriculum for Grade 2 learners that corresponds with the developmental level of respondents in Wu et al. (2012) quantitative study (DoBE, 2011b). As this research study focused on multiplication facts (mental mathematics: DoBE, 2011b) of which answers do not exceed 100 (according to South African Grade 4 curriculum specifications), all statements focussing on other number operations, were changed to similar problems containing *multiplication* operation(s) at Grade 4 level.

Fourthly, the ultimate aim of adapting the SEMA instrument was to make it more conducive to use as research instrument during a qualitative interview; using the adapted statements as interview statements (with added open-ended prompts to each statement) to elicit verbal responses from the participants and not to obtain quantitative data as in the case of the original instrument. The number of items on the adapted instrument needed to be reduced as it would probably consume more time than the sustained attention span of 10-year olds (approximately 11 minutes spent continuously on the task) (Medina, 2011). The researcher anticipated that the Phase 2 focus group interview (for which the SEMA instrument was adapted to be used as interview questions) would continue beyond the learners’ sustained attention period if the participants needed to also respond by explaining their choices to all questions after indicating a choice on the artefact.

Table 4.2 sets out abovementioned adaptations to the original instrument that took place during the first draft. The shaded sections indicate the adaptations.

Table 4.2. *First draft of the adapted SEMA instrument*

ADAPTATION: DRAFT 1

SCALE FOR EARLY MATH ANXIETY (adapted)

Instructions:"Now I'm going to show you some math questions. I want you to ***LISTEN TO*** *each question and pretend that you are going to answer it. Then I want you to* ***SHOW*** *me how nervous answering that question makes you feel.*

I also want you to tell me why do you think you will feel that way*.So remember, you do not actually have to answer the questions, but I just want you to pretend you are going to answer them and see how it makes you feel. It could make you feel not nervous AT ALL, a little nervous, somewhat nervous or very nervous. Do you understand?*

Practice Item: Let's do one together: "Who's the President of the RSA?" One more: "Who is the minister of Finance?"

1. George bought seven pizzas that had six slices each. How many slices did George have to share with his friends?
2. Is this right? 9 X 7= 64
3. How much money does Thabi have if she has two R5 coins and four 50c coins?
4. Write down the answer to 8 X 6 in words, not numbers.
5. A race started at 06:00 and Collen finished the race at 11:00. Collen's friend took twice as long to finish the race. When did he cross the finishing line?
6. Write down two multiplications sums that have exactely the same answer.
7. Recite the 7 times table from 12 X 7 to 1 X 7.
8. A big box of apples is packed in rows and layers. There are five layers. In each layer there are six rows with ten apples in each. How many apples are in the box.
9. Is this right? 5 X 8 = 40?
10. Yolanda gets twice the amount of pocket money than what Mpho gets. Mpho only receives half of what Carla is getting. Can you tell who gets the larger amount of pocket money?

Instructions: "Now I'm going to read you some sentences about situations that have to do with math. Try to pretend each situation is happening and think about how nervous it makes you feel. It could make you feel not nervous AT ALL, a little nervous, some- what nervous or very nervous. Do you understand? Let's try one. Pretend..."Practice Item: You're about to ride a roller coaster.

11. You are in math class and your teacher is about to teach something new.
12. You are in math class and your teacher is about to teach you how to multiply 34 by 14.
13. You are adding up all the money in your filled-up piggy bank. Mom wants to know how much money you would have saved if you saved 5 times as much.
14. You are buying lunch bar chocolates for you and seven of your friends. You are at the till and have to quickly calculate whether you have enough money.
15. You are about to take a math test.
16. You are in math class and you do not understand something. You ask your teacher to help you.
17. Your teacher gives you a lot of division problems to work on.
18. Your teacher gives you a lot of multiplication problems to work on.
19. You are in class doing a math problem on the board as to explain it to the rest of the class.
20. You are listening as your teacher explains to you how to do a word sum.

The adapted instrument (Table 4.2) was piloted on a sample of six Grade 4 girls during a qualitative group survey. This process constitutes the pilot project. The only aim of the pilot project was to obtain data on how to reduce the number of items original used as SEMA statements for the second and final draft. Parents/caregivers were contacted telephonically, the process was explained and informed consent was provided by means of text message to the researcher. The pilot project then commenced by the respondents being guided by the researcher through an activity whereby the ten items on Sisemore's (2008) nervous thermometer (Figure 4.4) were linked to the degrees of nervousness as stated on the artefact (Figure 4.3). The ultimate aim of this activity was to familiarise the respondents with the use of the artefact as it contained terminology involving *anxiety* also described as degrees of 'worry or nervousness". At no point in time, relations with or reference to Mathematics anxiety were made.

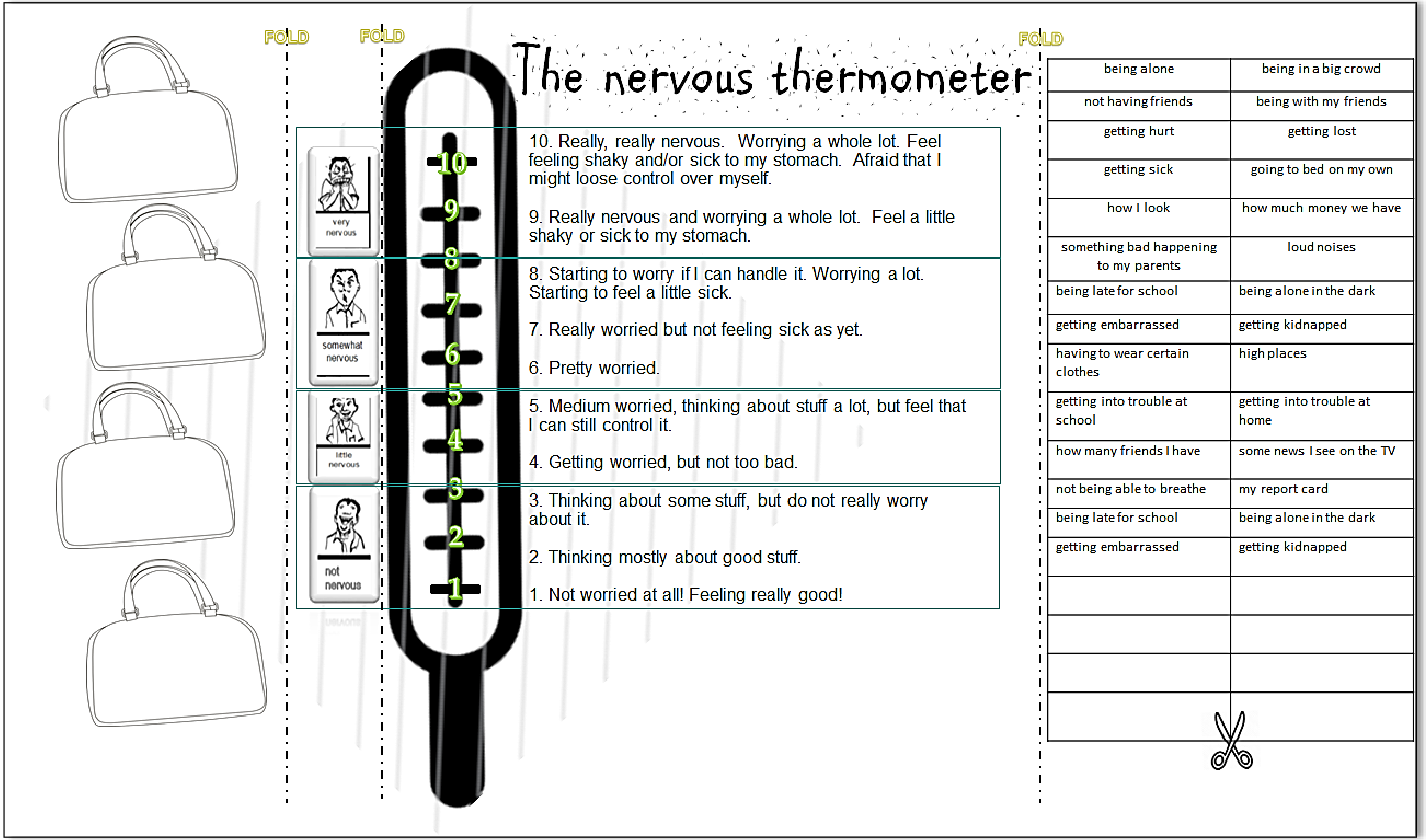


Figure 4.4. Activity sheet adapted from Sisemore (2008, p.21): Linking ‘nervous’ to ‘feelings of worry’

After linking, respondents were to place “worrying about…” sentences, in appropriate ‘bags’ as shown in Figure 4.4. Take note that the activity sheet was creased at the dotted lines and folded backwards so that only the Sisemore (2008) thermometer had been visible at the start. The artefact items (face drawings), bags and worry statements were only revealed at relevant moments of the guiding process. All of the respondents could understand the concepts introduced when mediating the ‘nervousness thermometer’. They also demonstrated their understanding of the ‘degrees of nervousness’ (replication of those used on the artefact) by appropriately matching phrases on the right of the activity sheet to the “bags” on the left. No further clarification was required and the pilot project could commence.

The researcher read all the adapted SEMA statements (Table 4.2) to the six respondents in a qualitative survey situation. Learners were seated in a semi-circle and each had to hold the artefact at chest height with their non-dominant hand. Respondents then indicated their degree of worry (simulated by the statement) putting their dominant hand's index finger on the corresponding picture or words on the artefact. The researcher as interviewer observed the reactions of the respondents and kept annotations of those items that seemed to be less clearly understood by one or more respondents. Sub-section 4.3.4 explains how the final adapted SEMA instrument emerged.

4.3.4 Instruments and procedures for the re-adaptation of the SEMA instrument (Phase 1A)

The original SEMA instrument was adapted and piloted to obtain information on how to reduce the number of items as described in sub-section 4.3.3. The researcher’s observational field notes were studied and by eliminating those statements that could possibly not be clearly and quickly understood by respondents eleven statements (SEMA items no 1, 3, 5, 6, 8, 13-17 and 19) remained to be taken up in the final draft of the adapted SEMA instrument. It was also realised that by paraphrasing the statements, it could even be better contextualised by contextualising the content and bringing it closer to the experienced world of the respondents. Furthermore, by adding open-ended prompts to be used if and when needed more and deeper interview responses could potentially be elicited.

The final format of the adapted and re-adapted SEMA questions, together with an example of open-ended prompts used in conjunction with the statements can be found in Table 4.3. It is this final format that served as one of the research instruments of Phase 2 of this study.

Table 4.3. *Final Draft: SEMA statement and open-ended prompts*

Instructions

Instructions:"Now I'm going to show you some math questions. I want you to ***LISTEN TO*** *each question and pretend that you are going to answer it. Then I want you to* ***SHOW*** *me how nervous answering that question makes you feel.* ***I also want you to tell me why do you think you will feel that way****.So remember, you do not actually have to answer the questions, but I just want you to pretend you are going to answer them and see how it makes you feel. It could make you feel not nervous at all, a little nervous, somewhat nervous or very nervous. Do you understand?*

Let's do one together: "Practice Item: "Who's the president of the RSA?" One more: "Who is the Minister of Finance?"

Original SEMA item number	***Paraphrased questions together with open-ended prompts.***
11	***George brought 7 pizzas that had 6 slices each. (Can you see the picture? Seven pizzas; six slices each.) How many slices did George have to share with his friends? Remember: don't calculate.*** Example of an open-ended prompt: "Can you explain why?"
3	***How much money does Thabi have in her hand if she takes out two R5 coins and four 50 cent coins from her purse?*** Example of open-ended prompts: "Why do think it was easier for you Learner E?"; "Why do think it is easier to work with money than plain sums on paper?"
5	***The school cross country race started at 6 o'clock and Collin finished the race at 11 o'clock, Collin's friend took twice as long to finish the race. When did his friend cross the finishing line? Don't give me the answers just tell me how nervous you are.*** Example of an open-ended prompt: "Why you say you're not good at working with time?"
6	***Teacher says: "Guys I am going to count up to 5 and in that time I want you to write down 2 multiplication sums that have got exactly the same answers". How would you feel?*** Example of an open-ended prompt: "So pushing you for time in maths is that a good thing or a bad thing? Why?"
8	***There is a big box of red apples packed in rows and layers. (Can you see the picture in your head?) There are 5 layers. In each layer there are 6 rows with 10 apples each. How many apples are in the box? The teacher says: "I want answers now! "***Example of an open-ended prompt: "I want to know who agree with her and why?"

The remaining 6 statements and open-ended prompts follow on the next page. Chapter (4a) will thereafter, in conclusion, describe the roles of the researcher and the research respondents during Phase 1A of the study:

(Table 4.3 continued from previous page)

Instructions: "Now I'm going to read you some sentences about situations that have to do with math. Try to pretend each situation is happening and think about how nervous it makes you feel. It could make you feel not nervous at all, a little nervous, some- what nervous or very nervous. Do you understand? Let's try one. Pretend..."Practice Item: You're about to ride a roller coaster.	
13	***Mommy tells you: "It is just one day before the holidays and I want you guys to empty your piggy banks." Your piggy bank is stuffed with all your change -only silver coins, no coppers. It means what kind of coins? R1, R2, R5 coins only. Mommy also says: "I'll give you 10 minutes. If you can count it correctly in those 10 minutes, I will give you 5 times more money" Will you be nervous?*** Example of an open-ended prompt: "Oh! So your mom disturbs you?" "How?"
14	***We are the fuelling station and mommy says "I am going to give you my purse and I want you to go inside and buy chocolates for you and any 7 of your friends." You are now at the till and you need quickly to calculate whether your mommy's got enough money in her purse. Because there is a long queue behind you and the person in front of the till says: "Come hurry up, hurry up! You want to pay or you don't want to pay?" Okay, so you need to really need to think quickly. I need to know how much money I need to have for 7 bars and quickly look if mommy's got enough money. How nervous will that make you?*** Example of open-ended prompts: "You have got a lot of confidence…?" "And if the shop keeper should tell you, you don't have enough money?"
15	***If I tell you we are going to write a mental mathematics test on times tables…. all the times tables….. Right now! Number from 1 to 10. I am going to go like this 5x8, 7x2, and 3x9. How nervous will you be?*** Example of an open-ended prompt: "Do you think a Grade R child can really understand times tables Learner F?" (After learner F stated "not nervous at all", because she knew all her times tables as from Grade R).
16	***You are in the math class and you do not understand what teacher is explaining. How do you feel if don't understand? On top of it all your teacher says: "I am not going to explain this once more, this is the last time explaining." And you still don't understand. How are you feeling?*** Example of an open-ended prompt: "How are you going to feel when you are putting up your hand?"
17	***Your teacher comes into class and tell you: "Listen I have lots of work to do for the principal. She gave me a lot of work, I want you to be quiet; therefore I am asking you to do these 100 multiplication sums but I want it back as it is going to count marks." How nervous will you be?*** Example of an open-ended prompt: "So he (referring to respondent's father) is drilling you?"
19	***You are in the math class and your teacher realises that a lot of kids are not mastering long division as they failed the test on long division written the day before. You only just passed the test but do not know it yet. Teacher then ask you to come and explain long division to the class on the board!!! How would you feel?*** Example of open-ended prompts: "You were all mixed up and you still did not understand?" "So, can you follow the steps of long division… all of them?"; "Why do you say a little nervous?"

4.4 The Roles of the Researcher and the Research Respondents (Phase 1A)

In a qualitative study, the researcher becomes the instrument mediating the data (Leedy & Ormrod, 2010). During Phase 1A, the researcher adapted the SEMA instrument by contextualising it to produce the first adapted draft and piloting and re-adapting it to produce a final draft for use as research instrument in Phase 2. The researcher scheduled introductory meetings with the respondents and contacted their parents/caregivers telephonically. The researcher also mediated and guided the introductory "nervous thermometer" activity with the pilot project respondents. The respondents were familiarised with the term "nervousness" that would be used to indicate their degree of "worry" when completing the adapted SEMA questionnaire during the pilot project. Finally, the researcher obtained findings and provided interpretations and conclusions to answer research sub-question 1.

Learners were invited as research respondents. An initial meeting was held with the criterion selected sample of six Grade 4 girls (selected by means of the processes set out in sub-section 4.3.2). During this introductory meeting the researcher guided the respondents through the "nervous thermometer" activity to better understand the degrees of worry and nervousness (refer to Figure 4.5 as well as sub-section 4.3.2). During the pilot project the respondents used an artefact as depicted in Figure 4.3 to indicate (by means of pointing) their emotional experience to each statement to the degree of nervousness/worry on their artefacts.

Ethical considerations concerning the researcher and the research respondents are discussed in sub-section 4.11.

4.5 Findings and Discussions (Phase 1A)

To optimise the value of the data on mathematics anxiety experiences in conventional learning environments from the focus group interview in Phase 2, Wu et al.'s (2012) SEMA instrument was adapted. The original quantitative research instrument was changed to an instrument that contained statements together with open-ended prompts to elicit participants' (in Phase 2) verbal responses. Through piloting the first draft, which was contextualised to the South African context in general, and the context of the National Mathematics curriculum (CAPS) specifically, the number of statements could be reduced. From the original 20 statements, the 11 statements that were found to be understood more clearly and responded to faster by the respondents, were kept. Open-ended prompts that could be used during the focus group interview to prompt for a deeper qualification(s) of participants' initial responses to a specific statement, were added as well.

Phase 1A of this study therefore presents one of the research instruments (adapted SEMA instrument – Table 4.3) necessary for Phase 2 to commence. This chapter will henceforward set out the research design of Phase 1B – a process that took place concurrently with that of Phase 1A.

4.6 Research Design: Phase 1B

The research design as set out in Table 4.1 of this chapter will be explained henceforward.

4.6.1 Determining game design criteria for answering research sub-questions 2 and 3 (Phase 1B)

In Phase 1B a literature review (set out in Chapter 3) was undertaken on 41 research studies[12] available to the researcher by means of the internet search engines referred to in Chapter 1 and published in English from 1981 to 2016. The purpose of this literature review was to identify game design criteria whereby two CAI games with the learning goal of automatising times tables' facts at Grade 4-level could be identified. Upon revealing the game design criteria in question, it was also compared to criteria for lesson design in conventional learning environments as set by Houser and DeLoach (1998) and Sale (2006), for improved verification of whether a CAI game not only fit the identified game criteria, but also fit the lesson design criteria (refer to Chapter 3, sub-section 3.2.9.)

On grounds of these criteria, the researcher also compiled teacher and learner questionnaires used as qualitative survey instruments in Phase 1B. The researcher distributed the teachers' questionnaires to the sample of 25 teacher respondents (by e-mail) and also arranged with the computer teacher at the

[12] Prominent research studies include that of Malone (1981), Lepper & Cordova (1992), Dondlinger (2007), Song & Zhang (2008), Whitton (2010), Huang et al. (2010), Felicia (2012) and Wouters et al. (2013)

research site to supervise the completion of learner questionnaires by the sample of 24 Grade 4 learners (from one class) at the research site.

The following research sub-questions lead to an investigation into the design criteria of CAI games:

Research sub-question 2: What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?

Research sub-question 3: Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?

4.6.2 Context of research site, population, sampling and respondents (Phase 1B)

To obtain a purposeful, yet representative, sample of games from which games for gameplay sessions in Phase 2 could be identified, the following procedures were followed. Figure 4.5 depicts the sampling procedure. An explanation of the procedures also directly follows the graphical representation.

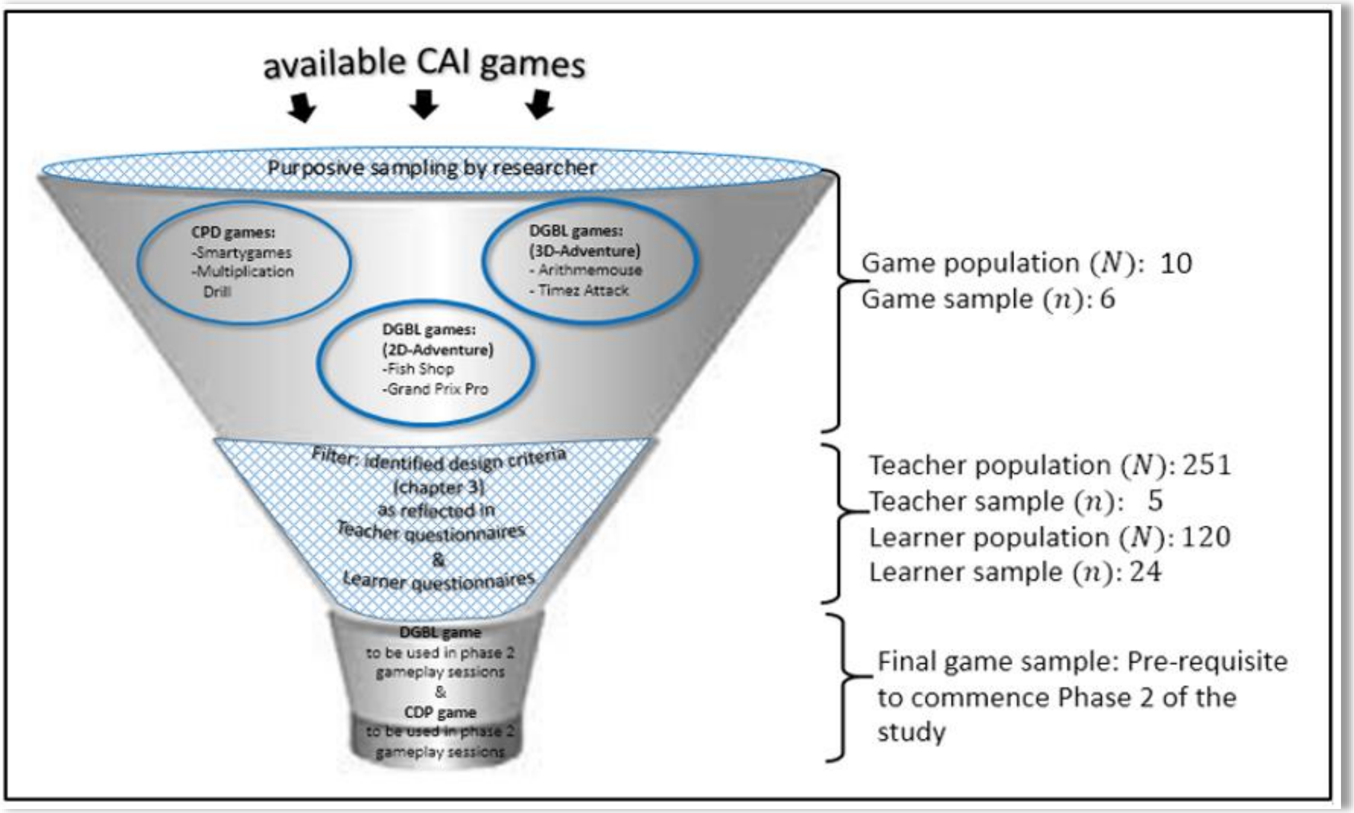


Figure 4.5. Phase 1B: Sampling procedures used in game identification

From the ten CAI games already familiar to learners and teachers of some grades at the research site, six games were identified by the researcher as examples of different CAI environments in which automaticity regarding multiplication skills could best be acquired. The following sampling criteria were applied to identify six suitable games to be evaluated in terms of the design criteria (refer to Chapter 3, Table 3.2). From the ten available games, the researcher first selected six games: the two *available* CDP games (Multiplication Drill – MD and Smartygames - Sg) and the two available DGBL games (3D-Adventure games: Timez Attack -TA and Arithmemouse- AM). From the remaining six games, the researcher gave preference to Grand Prix Pro (GPP) and Fish Shop (FS) as the latter two games were the only examples of 2D-games that could be accessed online to save on downloading cost. Apart from educational advantages, opportunities to automate multiplication bonds, cost, and age-appropriateness were major determining factors.

As the content regarding criteria (on which questions were to be asked) could not be adapted to the level of Grade 4 learners, teacher respondents were requested to answer questionnaires (Appendix C). In reflecting on the game design criteria, *immersion*, subjective input from learner players were to be obtained as adult players' immersion would differ from that of the age group that a specific game was designed for (refer to Chapter 3, sub-section 3.2.6). For this purpose, learner questionnaires were designed (Appendix D). Teachers, however, had to download and play the six games before completing the research questionnaires to reflect on their own gaming experiences. Download instructions were provided in the e-mail-correspondence, as well as website links which were also provided on the teachers' questionnaire (Appendix C). To put the reader in the context of these games the game genre, topic, classification, category, reference, type and cost are provided in Appendix E.

Teacher and learner respondents (who respectively completed the teacher and learner questionnaires in Appendices C and D) were identified by means of purposive sampling. From the 251 primary schools teachers (population) in one of the district clusters of Gauteng Education Department, a sample of 25 teachers from different schools from the same education district served as a convenient and purposive sample (Onwuegbuzie & Collins, 2007). As these teachers' e-mail addresses were known to the researcher[13], teacher questionnaires were e-mailed to the sample of 25 different teachers (teachers from the research site school were included). The only criteria was that the respondents had to be teaching Mathematics and/or Computer Literacy to a group of 9 to 10 year olds at the time.

All the learners (n=24) of one of the Grade 4 English classes (representing a population of 120 learners) were conveniently and purposively identified and invited to complete learner questionnaires on the DGBL design criteria of *immersion* (Appendix D). None of the identified sample of research participants for gameplay sessions in research Phase 2, were part of the sample grade 4 class.

4.6.3 Data collection instruments (Phase 1B)

4.6.3.1 Identified CAI games as research instruments to be used during Phase 1B

The design elements of CAI environments researched in Chapter 3 namely *interactivity, goal and rule structure, situational interest, challenge, game context, feedback* and *immersion* as well as the GameFlow model of Sweetser and Wyeth (2005) (explained in Chapter 3 and also set out in Table 3.2), empowered the researcher to select six from the ten CAI games already at the researcher's disposal. Sub-section 4.6.2 already described how the ten games were reduced to six by using the outcomes of the content analysis findings with which Chapter 3 concluded.

[13] Due to her position as Learning Support Educator in one of the education districts of the Gauteng Department of Education from 2005-2014, the researcher rotated between the identified schools, getting to know some of the teachers on a personal as well as professional level. Hence, being in possession of their e-mail addresses had not been unethical.

4.6.3.2 Teacher and learner questionnaires as research instruments

The identified game criteria from Chapter 3 also assisted to compile both the teacher and the learner questionnaires to conduct a qualitative survey. The purpose of these questionnaires was to provide the respondents with opportunities to reflect on their own gameplay experiences in both CDP and DGBL (See Appendices C and D). These experiences were not aimed at evaluating the attainment of the learning goal (automatisation of multiplication facts), but rather to identify the design criteria that would foster the automatisation of multiplication facts. When the teacher and learner questionnaires were analysed, the entire range of game design criteria as revealed through the literature study in Chapter 3, could be investigated. By analysing data from the returned teachers' and learners' questionnaires and drawing findings, the games most applicable as research tools for gameplay in Phase 2 of the research, emerged.

Teacher questionnaires were collected and analysed to obtain responses to whether the game design criteria of *game context, situational interest, rule and goal structure, challenge, interactivity,* and *feedback* were represented in each of the six games. Learner questionnaires yielded data on whether the six games represented the remaining game criteria, *immersion.* Since CAI games are designed for a specific player age group, adult players' (teachers') reflection on *immersion* would be inappropriate and invalid. *Immersion* is viewed as the only game design criteria that can only be evaluated by means of players' subjective game experiences (refer to Chapter 3, sub-section 3.2.6). Learner questionnaires were therefore designed to reflect only on *immersion*; omitting questions on this game design criteria from teachers' questionnaires.

The teacher questionnaire contained the questions in Sweetser and Wyeth's (2005) GameFlow model since it enabled reflection on the different game design criteria (Chapter 3, Table 3.2). The teachers' questions 1 - 4 refer to *interactivit*y; questions 5 - 8 to *goal and rule structure*; questions 9 - 12 to *situational interest*; questions 13 - 19 to *challenge*; questions 20 - 22 to *game context* and questions 23 – 27 to *feedback*. Following this distribution the learner questionnaire therefore only contained the last 4 questions from Sweetser and Wyeth's (2005) GameFlow model pertaining to *immersion*. These four questions were paraphrased and adapted to the context of the 9 to 10 year old South African learners partaking in the study. Question 29 was changed into two separate questions as it contained two variables namely "everyday life" and "the self". Table 4.4 illustrates these adaptations whereas Appendix D displays the format of the learner questionnaire on '*immersion*'.

Table 4.4. *Learner questions on immersion (adapted from Sweetser and Wyeth, 2005)*

SWEETSER and WYETH (2005) GAMEFLOW MODEL		ADAPTED QUESTIONS TO BE INCLUDED IN LEARNER QUESTIONNAIRE ON IMMERSION
No.	Questions	
28	Do players become less aware of their surroundings when playing a game?	During which of the games (if any) will you not even hear a plane going past?
29	Do players become less worried about everyday life or the self when playing the game?	During which of the games (if any) will you not even pay attention to the bell ringing for the end of the lesson period? During which of the games (if any) would you not even notice that it is freezing cold inside the classroom and that you have forgotten to put your jacket on?
30	Do players experience an altered sense of time when playing?	During which of the following games (if any) will it feel as if time is standing still and you are not even aware that a lot of time is passing?
31	Will players also be able to feel viscerally involved in the game, not only cognitively?	During which game (if any) can you go by what you *feel* like doing and answering- you do not only need to use your brain and *think, think* and *THINK*!

The first column of Table 4.4 refers to the numerical label of the question whereas the second column contains the question as found in the Sweetser and Wyeth (2005) GameFlow model. The third column sets out the adapted questions referred to in the previous paragraph. The learners responded individually to abovementioned questions as part of a qualitative survey. The learners were not provided the opportunity to share ideas with other learners and report back due to time restrictions as only a single 30-minute lesson period was made available by the principal. This aspect can be viewed as a limitation of the study as additional data (apart from nominating specific games) could have been obtained as well.

4.6.4 Data collection procedures (Phase 1B)

Prior to collecting data on the extent to which the sampled CDP and DGBL games reflected specific game design criteria, the game design criteria in question needed to be identified. The process through which this data set was obtained, is outlined in sub-section 4.6.4.1.

4.6.4.1 Collection of data by means of content analysis of CAI games

As set out in Chapter 3, the nature of design criteria of educational games were studied by scrutinising 41 studies published between 1981 and 2016 to point out the design criteria that could not only enhance cognitive, but also affective learning behaviours (refer to Chapter 3, Table 3.1). This content analysis revealed the design criteria that researchers nominated as primary determinates of cognitive and affective learning behaviours in games. The content analysis further focussed on the design criteria acclaimed for contributing towards *acquisition* of learning content. These focal design criteria were categorised under: *game context, situational interest, rule and goal structure, challenge, interactivity, immersion* and *feedback.*

4.6.4.2 Collection of data by means of teacher and learner questionnaires

The teacher questionnaires were distributed to 25 Computer and /or Mathematics Grade 4 teachers at the school research site as well as to teachers of neighbouring schools. The size of the convenient and purpose selected sample outnumbered the number of teachers at the research site matching the selecting criteria of being a Mathematics or Computer literacy teacher and teaching to 9-10 year old learners at the point in time. Teachers were requested to access two online CDP games as well as four DGBL games, play the games and then complete the questionnaires anonymously. Only five teachers responded and the questionnaires were randomly labelled as V, W, X, Y and Z. Teachers V to Y added detailed comments for their 'yes' or 'no' responses whereas teacher Z did not provide any comments.

The learner questionnaires were completed by a Grade 4 class (n=24) sampled from a population of 120 Grade 4 learners in the grade (N=120) during one of their computer-assisted Mathematics lessons. Due to logistic computer problems (slow download speed, insufficient internal processing speed and limited hard drive space) learners had not been able to actually play the games themselves. The teacher, however, projected the game onto an interactive white board in the class and randomly nominated different experienced game players (who volunteered to be nominated) to demonstrate how each of the games were played. The fact that learners were not able to experience the games first hand, resulted in reflections on possible immersion instead of personal experiences. This can be viewed as a limitation of the study. In attempt to compensate for this limitation, the player was a selected peer and not an adult. The possibility that learner respondents could therefore probably better identify with gameplay and be able to reflect on possible immersion, do exist. To eliminate "forced" and "forged" responses, learners were then requested to voluntary complete the questionnaire anonymously. To minimise the effect of the abovementioned limitations as learners could not engage in gameplay at first hand, screenshots of the game, together with the name of the game were added to the questionnaire to prevent confusion (refer to Appendix D). It was also explained by the teacher that the anonymous responses would benefit the researcher's study and would not count towards any subject, school assignment or assessment of any learner. The teacher read the five questions (indicated in the first column of the table in Appendix D) to the class and was requested to paraphrase, if needed, should it become evident that the researcher did not phrase the questions clear enough. No paraphrasing was requested from the learners. The teacher waited until all the learners indicated their choice(s) by means of an "X" in the columns of their choice before reading the following question. All learners (24) submitted their completed questionnaires.

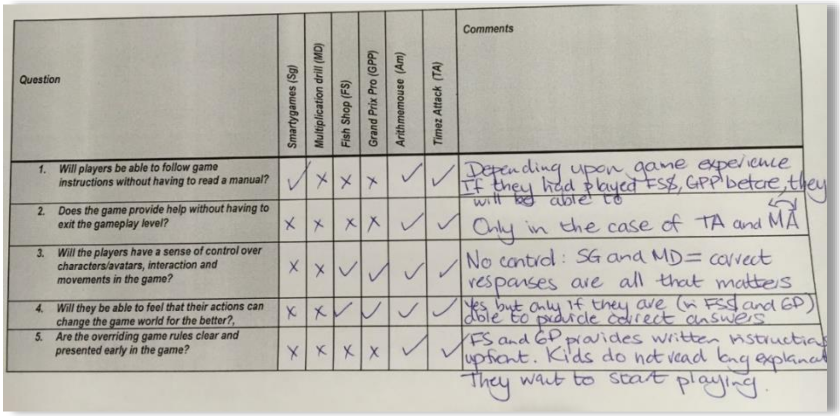
4.6.5 Data analysis (Phase 1B)

4.6.5.1 Content analysis of CAI games

Classical content analysis, as described by Leech and Onwuegbuzie (2007) were applied to analyse literature on CAI games so that categories emerged that could be interpreted as relevant game design criteria. Chapter 3, Table 3.1 displays the categories that emerged from the literature studies accessed by the researcher and the specific categories that different researchers outlined as credible game design criteria.

4.6.5.2 Analysis of the completed and returned teacher and learner questionnaires

The completed teacher and learner questionnaires yielded data that could be compared to the identified design criteria. It was therefore analysed by means of what Leech and Onwuegbuzie (2007) referred to as ‘*constant comparison analyses’.* The data sets obtained from teachers’ questionnaires contained two types of data: positive or negative *responses* (‘yes’ or ‘no’) and *explanations of their own positive or negative responses* (sentences or phrases). To provide clarity on abovementioned response/explanation distinction, Figure 4.6 provides an excerpt from one of the completed teacher questionnaires.



Question	Smartygames (Sg)	Multiplication drill (MD)	Fish Shop (FS)	Grand Prix Pro (GPP)	Arithmemouse (Am)	Timez Attack (TA)	Comments
1. Will players be able to follow game instructions without having to read a manual?	✓	X	X	X	✓	✓	Depending upon game experience If they had played FS$, GPP before, they will be able to
2. Does the game provide help without having to exit the gameplay level?	X	X	X	X	✓	✓	Only in the case of TA and MA
3. Will the players have a sense of control over characters/avatars, interaction and movements in the game?	X	X	✓	✓	✓	✓	No control: SG and MD = correct responses are all that matters
4. Will they be able to feel that their actions can change the game world for the better?,	X	X	✓	✓	✓	✓	Yes but only if they are (in FS$ and GP) able to provide correct answers
5. Are the overriding game rules clear and presented early in the game?	X	X	X	X	✓	✓	FS and GP provides written instructions upfront. Kids do not read long explanat[ions] They want to start playing.

Figure 4.6. Excerpt from completed teacher questionnaire to explain positive or negative responses (columns 2 to 7) and explanations (comments) of the responses (column 8)

The data sets obtained from learners’ questionnaires only consisted of (‘yes’ or ‘no’) responses for subjective experiences that could relate to immersion (Appendix D). The positive responses to all questions on the teachers’ and learners’ questionnaires were tallied and tabulated as to derive findings on the different game design elements that each game were said to portray. The maximum number of correct responses was also tabulated to infer the negative responses. The learner responses on immersion were tallied according to gender and tabulated separately as it had been anticipated that the sampled boys and girls could hold distinctively different gaming preferences: In this regard Garris et al*.* (2002, p. 446) state that “there are gender differences in computer usage and computer game preferences”. As the researcher anticipated that these different gaming preferences could possibly influence the *immersion* experiences to be reflected upon, it was preferred to record responses on possible *immersion* according to gender. Table 4.5 explains aforementioned tabulation.

Table 4.5. *Maximum number of positive responses on game design criteria (indicated as "yes" on teacher or learner questionnaires) to be completed during the analysis of teacher and learner questionnaire data*

	GAME DESIGN CRITERIA	*MAXIMUM NUMBER OF POSITIVE RESPONSES	CDP GAMES		DGBL GAMES			
					Adventure games		3D-Adventure games	
			SG	MD	FS	GPP	Am	TA
TEACHER QUESTIONNAIRE (Q1- Q27)	**INTERACTIVITY** Q1-Q4	20						
	GOAL & RULE STRUCTURE Q5-Q8	20						
	SITUATIONAL INTEREST Q9-Q12	20						
	CHALLENGE Q13-Q19	35						
	GAME CONTEXT Q20-Q22	15						
	FEEDBACK Q23-Q27	25						
LEARNER QUESTIONNAIRE (q1-q5)	**IMMERSION** q1-q5 (n=10 BOYS)	50						
	IMMERSION q1-q5 (n=14 GIRLS)	70						

***MAXIMUM** NUMBER **OF POSITIVE RESPONSES refers to the number of questions (Q) multiplied by the number of participants/respondents**

Teachers' *explanations* for their own 'yes' or 'no' responses were firstly translated into English where necessary, as two teachers commented in Afrikaans. Thereafter the researcher categorised the data by means of deductive reasoning under the following components of each design criteria. The components are placed in parenthesis.

- Interactivity (through *dialoguing*, *controlling* and *searching*)
- Goal and rule structure (*rigid rule and goal structure hindering gameflow* or *smooth and flexible rule and goal structure facilitating gameflow*)
- Situational interest (*sensory stimuli, curiosity and mystery* and *fantasy*)
- Challenge (*sensible cognitive load, performance before competence and guarding against overload of the working memory)*
- Game context (*no plotline, fixed plotline* or *flexible, self-chosen plotline*) and
- Feedback (*reflection, transfer and automaticity)*

The data analysis of the teachers' comments were then extended by aligning these comments to the three components of Song and Zhang's (2008) EFM model for effective educational game design. The components of the EFM model are: *Criteria for creating effective learning environments*, *Dimensions of flow experience* and *Strategies for stimulating motivation*. After categorising the comments general themes emerged that (together with the analysis of game design criteria) resulted in nominating the most conducive games to be used as research instruments in the second research phase.

The findings derived after analysing both these data sets, led to the selection of appropriate CAI games to be utilised as research tools during the gameplay sessions of Phase 2. The entire process of analysis up to the point where the researcher decided to include both DGBL games to prevent possible gender bias, will be explained in Chapter 6.

4.7 The Role of the Researcher and Respondents: Phase 1B

The researcher was responsible for analysing the collected data, deriving findings, providing interpretations and conclusions, in order to answer research sub-questions 2 and 3. The teacher respondents were requested to download or play six different games online before completing questionnaires on their gameplay experiences. Learner respondents also attended to gameplay demonstrations in class before completing their questionnaires on the game criteria of *immersion.* Other roles resort under ethical considerations and will be discussed in sub-section 4.11.

4.8 Findings and Discussions: Phase 1B

Although only five completed teacher questionnaire data sets were submitted, four of these teachers provided detailed explanations (not only yes or no responses) to *all* questions. The detailed explanations were unexpected, and valued as it provided invaluable data to be analysed in a qualitative study. The process whereby these data sets together with the data on immersion from learner questionnaires were analysed in order to nominate the CAI games in both CDP and DGBL environments, will be set out in Chapter 6.

4.9 Triangulation

Triangulation is the amalgamation of no less than two data sources, theoretical perspectives, methodological approaches, investigators, or methods of data analysis (Thurmond, 2001). The purpose of using triangulation, according to Mouton (2012), Thurmond (2001) and De Vos (2005), lies in decreasing, negating, or counterbalancing the deficiencies of a single strategy; thereby increasing the potential to interpret the research findings.

When reviewing the entire research design, the following types of triangulation were applied to enhance understanding of the phenomenon stated in the research title: data source, method of data collection and data analysis triangulation. Thurmond (2001) distinguishes between across-method triangulation and within-method triangulation. Where across-method triangulation refers to both qualitative and quantitative methods used in a single study, within-method triangulation refers to the use of at least two data-collection and analysis procedures from the same design approach. The discussion on triangulation will therefore proceed by outlining the within-method triangulation attended to in this study.

In this chapter, only the types of triangulation pertaining to the triangulation methods within the first research phase are put forward. As per definition of triangulation ("seeking convergence and corroboration of results from different analytical methods used on the same data"), triangulation between research procedures of Phases 1A and 1B cannot be established as different data sets are accessed (Leech & Onwuegbuzie, 2007, p. 580). In Chapter 5, it will however be revealed how Phase 1A and Phase 1B can be triangulated with the research procedures of Phase 2. Chapter 5, sub-section 5.7 will therefore not only reveal the triangulation within the second research phase but also set out the triangulation between the three components of the research design (Phase 1A, Phase 1B and Phase 2).

4.9.1 Triangulation: Phase 1A

Data source and data collection triangulation: Verbal data (SEMA- questionnaire) and non-verbal data (gestures) were collected through sourcing the SEMA instrument (Wu et al., 2012) and during piloting the adapted SEMA instrument respectively.

Data analysis triangulation: Leech and Onwuegbuzie (2007) prefer qualitative researchers to apply two or more data analysis instruments to be able to triangulate results. During Phase 1A '*classical content analysis*' (Leech & Onwuegbuzie, 2007) was undertaken and assisted by '*key-word–in-context*' method of analysis: To adapt the SEMA instrument to the South African context of lived experiences and Mathematics curriculum for Grade 4 learners as well as the concentration span of 10 year old learners in a focus group interview, possible themes denoting inappropriate contextual content, had to be identified through content analysis. To further refine items, a second round of analysis took place by observing respondents' (not participants') reactions; non-verbally communicating their responses. By attending to the way in which they reacted to the emphasized key word phrases in the statement, it could be inferred which questions were understood less clearly and could possibly be omitted in the final draft.

4.9.2 Triangulation: Phase 1B

Data source and data collection triangulation: In this research phase different types of verbal data were used in order to prepare research instruments to be used in the second research phase. Verbal responses (written text) were obtained from teachers' as well as learners' questionnaires. Verbal data were furthermore obtained by conducting a literature review (Chapter 3) that enabled a content analysis of CAI game design criteria.

Data analysis triangulation: '*Classical content analysis'* (Leech & Onwuegbuzie, 2007) was applied in analysing the literature on CAI games as it involved categorising findings from literature into categories that emerged from literature (refer to Chapter 3, Table 3.1 for categories). When analysing the data from teacher and learner questionnaires to be able to nominate a conducive CDP and DGBL game as research tools for Phase 2, '*constant comparison analysis'* were used as the researcher focussed on asking only two general overarching questions (Research sub-questions 2 and 3) to compare game criteria displayed by CDP and DGBL games respectively (Leech & Onwuegbuzie, 2007).

By combining different types of data and different methods whereby the data is collected and analysed, the researcher seeks to validate the interpretations derived from the findings of Phase 1A and

1B respectively – enhancing the quality of the respective research instruments as the end product of Phase 1.

4.10 Summary of the Research Design (Phase 1A and 1B)

This qualitative research study followed a multi-method, multiple case study design. It culminated in a multi-stage and multi-facet sequential design that took place during two distinct sequential phases. These two phases were outlined in the introduction to this chapter. Figure 4.1 presented a detailed graphical representation of the first research phase. Figure 4.7 provides a holistic view of the different components of Phase 1 by outlining *how* Phase 1 culminated into Phase 2. Figure 4.7 also depicts the way in which the different types of content analysis in Phase 1A and Phase 1B produced the research instruments (tools) by which the research activities of Phase 2 could commence.

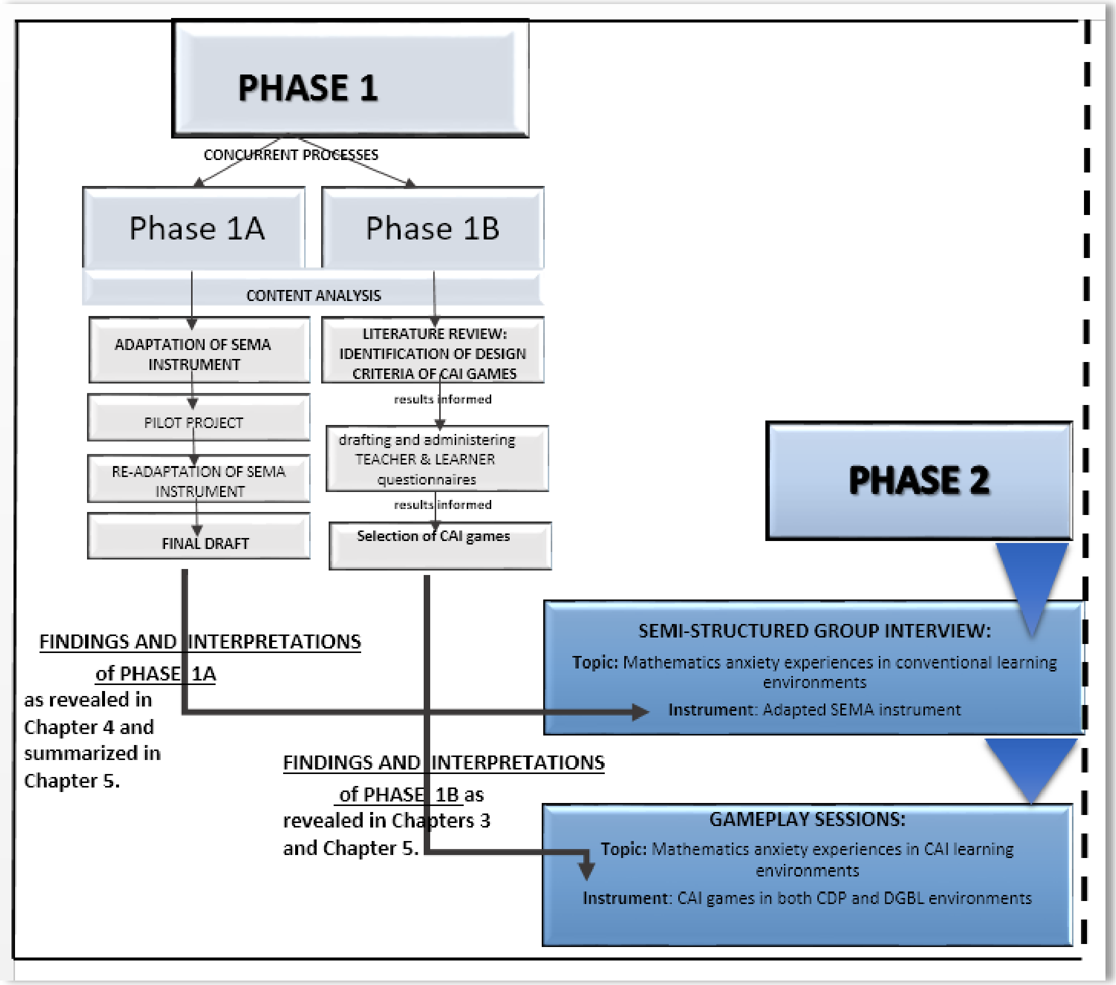


Figure 4.7. How research findings of Phase 1A and 1B enabled commencing Phase 2.

The adapted SEMA instrument provided the research instrument (statements and open-ended prompts) by which a focus group interview at the very beginning of Phase 2 could be conducted. The CAI games singled out as research findings of Phase 1B, in turn, served as the research instrument by which the data collection (gameplay sessions) *during* Phase 2 could take place.

As the research study took place in two different phases, the findings were therefore also presented in two parts: Chapter 6 presents the findings of the first analysis phase (Phases 1A and 1B) and Chapter 7 presents the findings from the second analysis phase (Phase 2).

4.11 Ethical Considerations

Ethical guidelines serve as standards against which researchers ought to evaluate their own conduct (Strydom, 2005). Ethical principles are thus internalised in the personality of the researcher and all decisions regarding the research will therefore rest upon personal moral principles. Informed permissions from relevant authorities, institutions, Grade 4 learners' assent, and the consent of their parents/caregivers as well as the informed consent from teacher respondents were obtained prior to the study. As the research project was undertaken in a primary school in Gauteng, formal permission from Human Resources (HR) department at the Gauteng Department of Education was obtained after ethical clearance was granted from the Ethics Committee of the Northwest University (NWU-00103-14-A2). The school principal and school governing body at the research site also provided their informed consent.

Arrangements were made with the school to agree upon timeslots outside contact hours so as not to disrupt teaching and learning. Written consent was obtained from each of the parents/caregivers of the six learners taking part in the pilot phase of the study and the parents/caregivers of the six research participants. In this part of the study identities were protected and learners were only referred to as leaner A, B, C, D, E and F or participant A, B, C, and D during Phase 2. Participation was voluntary and respondents/participants were allowed to withdraw at any point in time. The aim and procedures of the study was explained in the informed assent letter as well as verbally mediated to learners at their own developmental level of understanding during a briefing session preceding the study. The parents/caregivers represented was provided unlimited opportunity to ask clarifying questions to which the researcher responded. Parents/caregivers were also requested to respond to questions on the minor's computer gameplay behaviours indicated in the consent form (Appendix F). They were only requested to respond by indicating the frequency of exposure to computer gameplay as 'twice or more per week', 'once a week' or 'never'.

In responding to the teacher or learner questionnaires, the following ethical issues were encountered. As teachers were requested to play the selected games online before completing the survey questionnaire, it could not be ascertained whether the games were played or whether game descriptions were merely accessed online. The learner respondents were, due to practical reasons, not able to experience the gameplay first handed. This could have impacted negatively on the learners' objectivity when reflecting on observed gameplay experiences. Abovementioned scenarios could have impacted negatively on not only the outcomes, but also the trustworthiness of Phase 1B and therefore the entire study.

Other ethical considerations pertaining to the study will be exposed in Chapter 5.

4.12 Challenges and Problems Encountered

It needs to be taken into account that although respondents invited to take part in the pilot project were prepared beforehand (refer to sub-section 4.3.3), the possibility of respondents' responses being more hesitant due to unfamiliarity with the unfamiliar psycho-social environment[14] do exist. Apart from the general anxiety that responding could instil in respondents, no other out of the ordinary behaviours could be observed during the pilot project.

From the 25 teachers' questionnaires distributed, only five were completed and returned. Although the data accumulated yielded sufficient evidence to be analysed, there is no way in which the researcher could declare that all of the six games were actually accessed and played by all of the five respondents. These teachers could have responded according to what was read about the game instead of actually playing the game as the websites that they were requested to access in order to play the games online, also included a description of the game.

When learners responded to immersion (as expected on learners' questionnaire), they could not play the relevant games themselves (refer to sub-section 4.6.3.2). They only attended to demonstrations of the games, and so they were requested to reflect on *possible* immersion. If learners actually played the games, data could have been somewhat different in nature.

Where Figure 4.7 already orientated the reader by means of graphical representation towards the second research phase, Chapter 5 will henceforward provide a detailed description of the research activities of Phase 2.

[14] Learners are affected by the surrounding social (relationships, tradition and culture) and psychological (thoughts, emotions, and behaviour) conditions that may influence the quality and effectiveness of their experiences (http://www.unesco.org/new/en/education/themes/strengthening-education-systems/quality-framework/technical-notes/the-psychosocial-environment.)

Chapter 5
The Qualitative Research Design: Phase 2

5.1 Introduction

Chapter 5 will set out the procedures related to the second research phase (Phase 2) and focuses on the analysis of learners' *anxiety↔confidence* valence as manifested in conventional learning environments (Phase 2A) and CAI learning environments (Phase 2B). Different types of verbal and non-verbal data sets were collected and analysed. While participants' *anxiety↔confidence* experiences in conventional learning environments were examined by means of focus group interview data (verbal data), their *anxiety↔confidence* experiences in different CAI environments (CDP and DGBL) were studied by means of video-recorded gameplay data (non-verbal data) and data obtained through individual post gameplay interviews (verbal data).

Table 5.1 provides an overview of the research design of Phase 2 – outlining the data collection methods, the purpose of research conducted in Phase 2 and the methods whereby the data were analysed. The corresponding research sub-questions that informed the investigations within the different learning environments are also reflected. Table 5.1 also refers the reader to the relevant chapter (Chapter 7) in which the research findings will be exposed.

Table 5.1. *Overview of research design: Phase 2*

	Main research activity	Data type & Method of data collection	Purpose	Analysis procedure	Findings revealed in Chapter 7, sub-sections…
Phase 2A	**Describing learners' affective experiences (*anxiety↔confidence*) during automatisation of multiplication facts in conventional learning environments** Research sub-question 4 *To what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts?*	Focus group interview Data type: verbal (*verbatim* transcriptions of audio recordings) Use final draft of adapted SEMA instrument as interview statements to a qualitative sample (six Grade 4 learners)	To investigate learners' anxiety experiences in conventional teaching and learning environments (classroom and home)	Inductive reasoning: categorisation and interpretation in terms of common themes (Atlas.ti)	7.3.1
Phase 2B	**Describing learners' affective experiences (*anxiety↔confidence*) during automatisation of multiplication facts in CAI learning environments** Research sub-question 5: *To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?* Research sub-question 6: *To what extent, if any, do Grade 4 learners experience anxiety in DGBL learning environments during the automatisation of multiplication facts?*	Video-recorded gameplay sessions Data type: non-verbal (audio and visual) Three individual gameplay sessions with each of the four participants. Three different games aiming at automatisation of multiplication facts were used as research tools, Individual post-gaming reflections Data type: verbal (*verbatim* transcriptions of audio recordings) Semi-structured interview questions to elicit individual self-reflective responses on gameplay experiences.	To investigate the anxiety experiences within CDP and DGBL environments while automatising multiplication facts	Inductive reasoning: categorisation and interpretation in terms of common themes (Atlas.ti)	7.3.3 (CDP learning environments) 7.3.4 (DGBL environ-ments)

The reader is requested to take cognisance of the fact that the researcher's assumptions (Chapter 4, sub-section 4.1.1), the theoretical assumptions (Chapter 4, sub-section 4.1.2) and the paradigmatic perspective (Chapter 4, sub-section 4.1.4) also forms the bedrock for the second phase's research activities as described in this chapter.

Figure 5.1 sets out the sequential processes of the research design as it unfolds in Phases 2A and 2B respectively. In addition, Figure 5.1 also highlights the reasons and frameworks for analysis as well as the analysis procedures. It also points to how the preliminary findings of each step, culminated into answering to the main research question (final findings). The interpretation hereof will be exposed in Chapter 8.

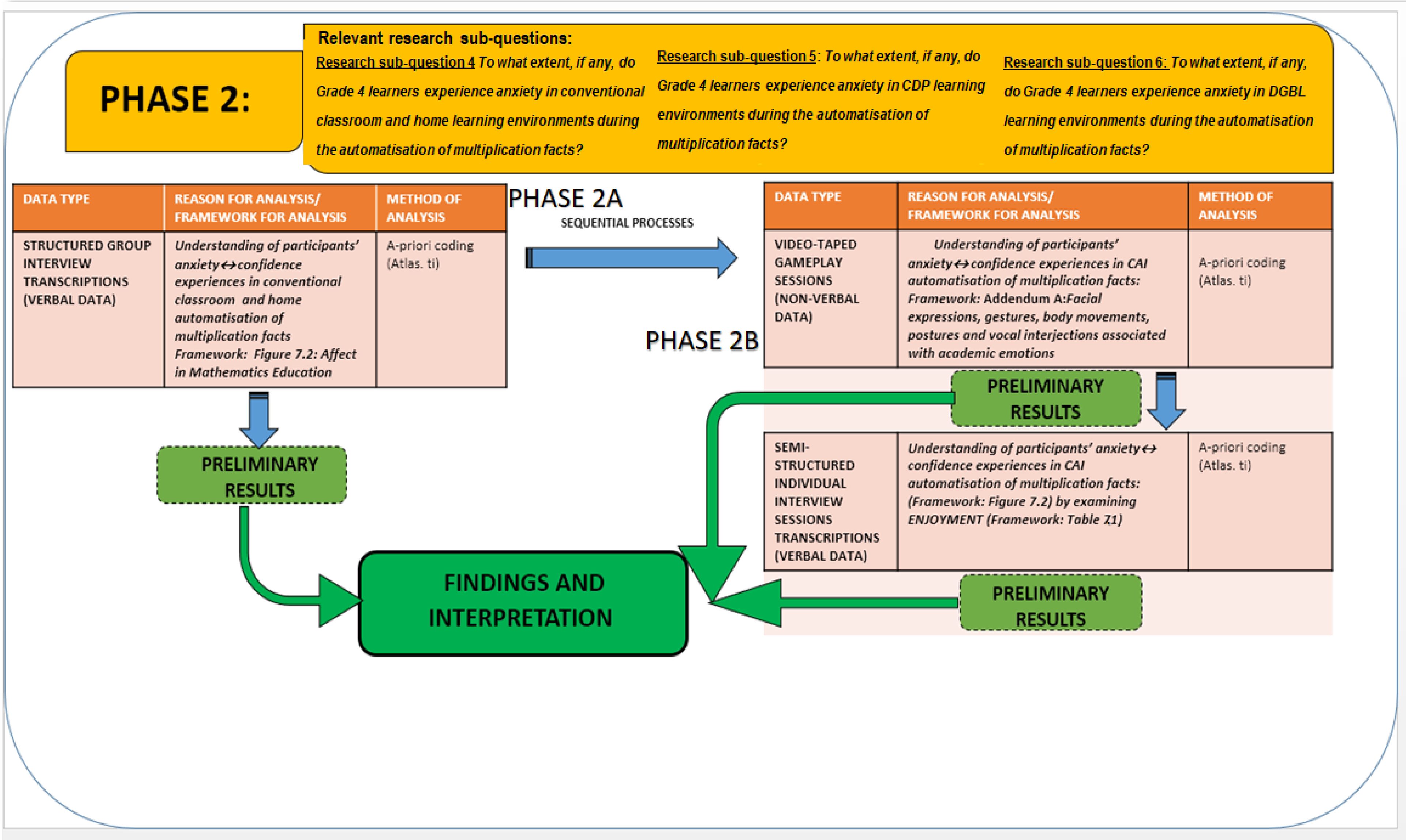


Figure 5.1. Phase 2: sequential research processes of Phase 2A and Phase 2B

The research methodology applied in Phase 2A therefore focuses on data collection and analysis processes to answer to research sub-questions 4:

Research sub-question 4 (RSQ 4): To what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts?

Subsequently, the remaining two research sub-questions informed the research methodology of Phase 2B:

Research sub-question 5 (RSQ 5): To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?

Research sub-question 6 (RSQ 6): To what extent, if any, do Grade 4 learners experience anxiety in DGBL learning environments during the automatisation of multiplication facts?

This chapter proceeds by outlining the similarities and differences between the research context, sampling procedures, populations and respondents/participants of Phase 1 in relation to that of Phase 2A and Phase 2B.

5.2 Research Context, Population, Sampling and Participants

The research context of Phase 1A as described in Chapter 4, sub-section 4.3.2 serves as the context of Phase 2. The only difference lies in the fact that the research context of Phase 2A and Phase 2B only included learners and activities that took place at the research site. No school or individuals from outside the school were involved[15].

Phase 2A of the study commenced with an initial sample of six participants (not to be confused with the six participants that took part in the pilot project of Phase 1A). The sampling procedure for selecting interviewees for the first focus group interview followed the same procedure as that of selecting participants for the pilot project conducted in Phase 1: A criterion sample of six (n=6) participants from the population of 120 (total number of Grade 4 learners in English classes at the research site) were invited to take part (Nieuwenhuis, 2007). These participants were part of the remaining three English Grade 4 classes at the research site. The class, whose learners formed part of the qualitative survey were omitted as the learners were already exposed to the content of the different games that emerged as research tools used in this research phase (Phase 2B). As in criterion sampling for the pilot project, chronological age within close range and same gender served as selection criteria. Chapter 4, sub-section 4.3.2 explains why the abovementioned invitation criteria were applied. At this point, the researcher would like inform the reader that the researcher was also granted permission to access data on the participants' weekly mental mathematics assessments as (per research proposal) the data would initially serve as a selection criterion. The researcher nevertheless kept anecdotal notes that served as additional data when interpreting the findings of this research phase.

[15] *The researcher is a staff member at the research site. She is employed as a non-teaching staff member and can therefore not be regarded as an outsider.*

After the focus group interview, another round of sampling took place and the number of participants to be invited to take part in the gameplay sessions, and subsequent post gameplay activities, were reduced to four to be aligned with Onwuegbuzie and Collins' (2007) sample specifications of three to five participants for a case study design. The four most experienced gamers continued, in favour of the two learners with the least experience, to minimise the chances of limited gaming experience that would negatively impact on the overall gaming experiences. Chapter 5 will proceed by describing the research processes followed during Phase 2A and 2B respectively.

5.3 Research Design: Phase 2A

5.3.1 Data collection instrument: Adapted SEMA items and open-ended prompts

In answering the research sub-question 4, the adapted SEMA instrument prepared during research Phase 1A, was used to collect data during a focus group interview. Table 5.2 reflects the instrument, relevant research sub-question, data type and reason for collection whereas sub-section 5.3.2 provides a detailed explanation.

Table 5.2. *Synopsis: data collection instruments (Phase 2A)*

INSTRUMENT	RESEARCH SUB-QUESTION(S)	TYPE OF DATA	RATIONALE	PARAGRAPH
Adapted SEMA items and open-ended prompts (Chapter 4, Table 4.3)	**RSQ 4** *To understand to what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home instructional environments during the automatisation of multiplication facts?*	Verbal	To identify (if any) and describe learners' anxiety experiences in conventional instructional environments	5.3.1

Chapter 4, Table 4.3 displays the final format of the adapted SEMA items with added open-ended prompts. During the first research phase, the SEMA questionnaire of Wu et al. (2012) was adapted from a quantitative research instrument consisting of 20 items into 11 qualitative interview questions used as the research instrument whereby the focus group interview in this research phase was conducted. The rationale for limiting and contextualising the SEMA items was revealed in Chapter 4, sub-section 4.3.1 The 5-point Likert scale that the original SEMA instrument (Appendix B) utilises to indicate participants' responses was abandoned in favour of a 4-point Likert scale. The reasons for this adaptation were also explained in sub-section 4.5.2. To make the adapted instrument even more conducive to eliciting responses during an interview, open ended prompts were included. This item from the final draft (Table 4.3) explains the prompts: ***You are in the math class and your teacher realises that a lot of kids are not mastering long division as they failed the test on long division written the day before. You only just passed the test but do not know it yet. Teacher then ask you to come and explain long division to the class on the board! How would you feel?*** Example of open-ended prompts: "You were all mixed up and you still did not understand?";"So, can you follow the steps of long division… all of them?"; "Why do you say a little nervous?"

During the actual interview more situational prompts were added by the researcher, because, as interviewer, she anticipated additional responses to be revealed. The prompts included in Table 4.3 only serve as an example. The reader is referred to the transcription of the focus group interview (available on CD) for the entire array of prompts.

5.3.2 Data collection procedures: Phase 2A

Table 5.3 provides a synopsis of the data collection instruments of this phase and also outlines the data collection and analysis procedures. The data collection and analysis procedures are, however, expanded by means of Table 5.3 and described in this sub-section and sub-section 5.3.3.

Table 5.3. *Synopsis: data collection procedures: Phase 2A*

DATA TYPE	RESEARCH SUB-QUESTION(S)	DATA COLLECTION PROCESS	RATIONALE	SUB-SECTION
Focus group interview: (verbal data)	***RSQ 4*** *To understand to what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home instructional environments during the automatisation of multiplication facts?*	Focus group interview *verbatim* transcription of audiotaped Material. Researcher's observations(field notes)	To identify (if any) and describe learners' anxiety experiences in conventional instructional environments.	5.3.2.1

5.3.2.1 Collection of verbal data (focus group interview)

The researcher interviewed the six criterion-sampled research participants as described in sub-section (5.2) after informed consent had been obtained from parents/caregivers as well as assent from the participants. Parents/caregivers and learners were invited to an informal information session. All prospective participants and parents/caregivers of four learners were present. The informed consent letters were sent home to the remaining parents. The forms were signed and returned the following day. All parents/caregivers and learners therefore signed the consent/assent forms.

The research then proceeded with the scheduled focus group interview. The re-adapted, open-ended SEMA questions were used as interview statements. The researcher also made use of the prepared prompts to elicit more and/or deeper responses[16]. Examples of these open-ended prompts can be found with the final draft of the SEMA items in Chapter 4, Table 4.3. Although participants responded as part of a *group*, an artefact (as described in sub-section 4.3.3 and depicted in Figure 5.2) was used to elicit and indicate more spontaneous *individual* responses. In this way, participants could *all* (simultaneously) indicate their individual responses without speaking. The researcher, as interviewer, then used open-ended prompts to elicit individual verbal responses

[16] Refer to transcription of the focus group interview (available on electronic storage device).

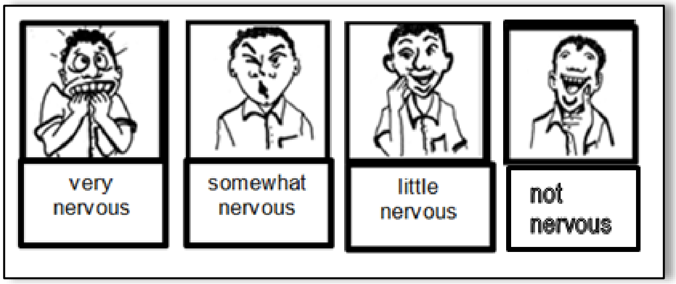


Figure 5.2. Artefact assisting research participants in responding to the adapted SEMA statements. (Adapted version of Baker's (2005) faces as cited in Cravero et al., 2013)

The focus group interview was audio-recorded and transcribed *verbatim* afterwards.

5.3.3 Data analysis procedure: Phase 2A

The transcriptions of the verbal data from the focus group interview were analysed by means of Atlas Ti software. The constructs revealed in the literature study in Chapter 2, sub-section 2.4.2 and Figure 2.7 were used to allocate a-priori codes for analysis purposes. These constructs together with the coding thereof follow in Table 5.4 below. The allocated codes are depicted in the shaded columns. The broken line in Table 5.4 below refers to the interplay between the domains of academic emotions and beliefs and attitudes about mathematics and Mathematics. This interplay will be briefly discussed following Table 5.4 and depicted by means of Figure 5.5.

Table 5.4. *Codes (in shaded columns) used during coding of focus group interview data*

ACADEMIC EMOTION CONSTRUCTS (Chapter 2, sub-section 2.4.2)									
Labelling of academic emotions		**Construction of academic emotions**		**Outcome focus**		**Position of constructed academic emotions**		**Beliefs and attitudes (left) and domains of academic emotions (right) The matrix below (Figure 5.5) reveals the coding of the interplay between these two constructs.**	
confidence	**C**	predominantly self-constructed	**A**	focussed on *achievement outcomes*	**1**	trait position	*	about mathematics	cognitive
anxiety	**ANX**								
enjoyment	**ENJ**			focussed on *task at hand*	**2**			about the self	affective
boredom	**BRD**								
shame	**SH**			focussed on *task avoidance*	**3**			about the social context	physiological
pride	**PR**	predominantly socially-constructed	**B**			state position	**		
relief	**R**			focussed on *retrospective activities*	**4**			about the teaching and learning of Mathematics	Motivational
hopelessness	**HL**								
gratitude	**GR**								
anger	**ANG**								

Beliefs and attitudes regarding mathematics are domain specific (refer to the framework for attitude and belief domain origins of academic emotions as explained in Chapter 2, sub-section 2.4.2). The domains of academic emotions (related to mathematics in general and as a subject) in which beliefs and attitudes (about mathematics, the self, the social context, teaching and learning of Mathematics) are formed, could be coded by means of a matrix (Figure 5.3) using codes X1 to X24.

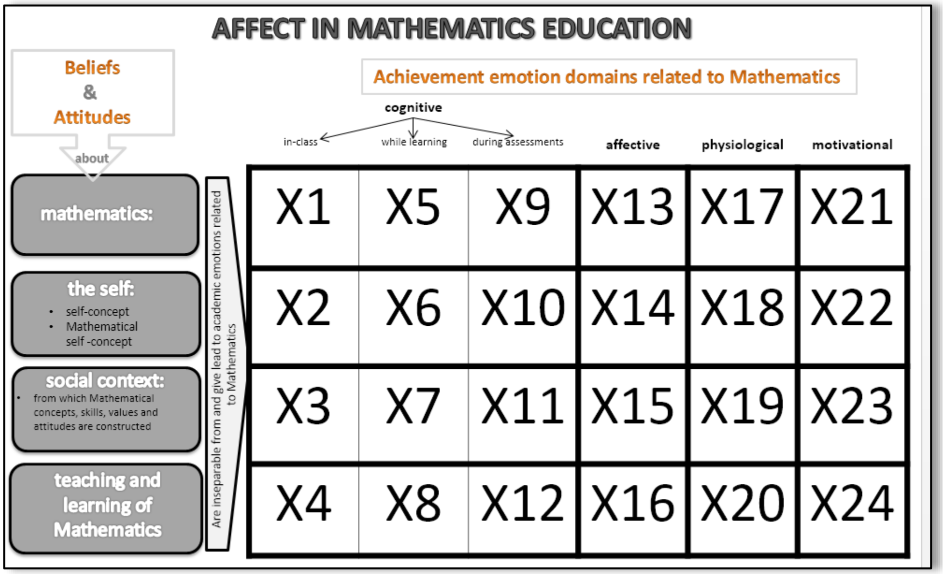


Figure 5.3. Coding of attitude and belief domains (X1 to X24), utilising Figure 2.7 from Chapter 2

To clarify and to enhance analysis, transcriptions were annotated. The annotations were saved as memos. A typical distribution of codes (as displayed in the snapshot of a network view) is depicted in Figure 5.4. The figure also illuminates the coding process by referring to a quotation from the transcribed focus group interview.

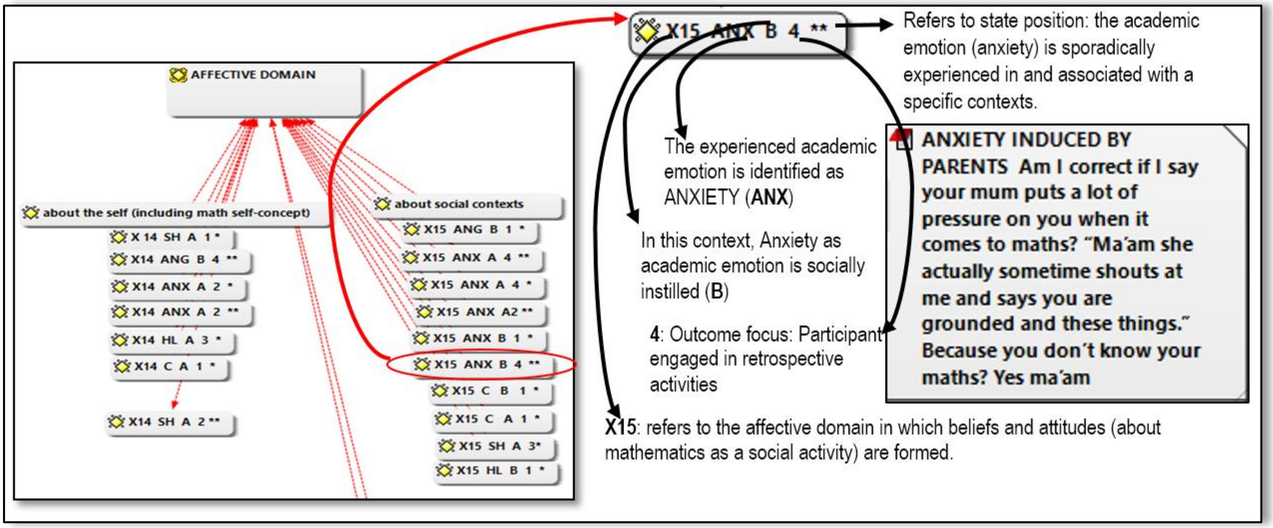


Figure 5.4. Example of coding focus group interview data (left) and clarification of the coding (right)

As the relevant secondary research question entails understanding Grade 4 learners' anxiety experiences in *conventional learning environments* (at school and home), Atlas Ti network views were compiled after coding to support analysis procedures. The following secondary, yet complementary themes (for which network views were compiled) evolved to assist investigation and analysis:

- *Confidence* (self-constructed) and confidence (socially instilled) as well as the positive attribution origins (domains) thereof.
- *Anxiety* (self-constructed) and anxiety (socially instilled) as well as the negative attribution origins (domains) thereof. Although not directly related to *anxiety↔confidence* experiences, Pekrun et al*.* (2002; 2011) and Villavicencio and Bernardo (2013; 2015) urge researchers investigating a specific academic emotion (for example *anxiety*), that the entire spectrum of academic emotions as needed, should to be taken into consideration and as many as possible emotional (*confidence, anxiety, pride, shame, enjoyment, boredom, relief, hopelessness and anger)* experiences should be examined to provide a well-rounded account of the experiences relating to a specific academic emotion. The focus group interview data were therefore also scrutinised for:
- *Pride, relief*, and
- *Shame, hopelessness, anger* and *boredom* as auxiliary, yet complementary emotions to that of confidence and anxiety.

Figure 5.5 depicts snapshots from the AtlasTI network view constructed to support the analysis of interview data.

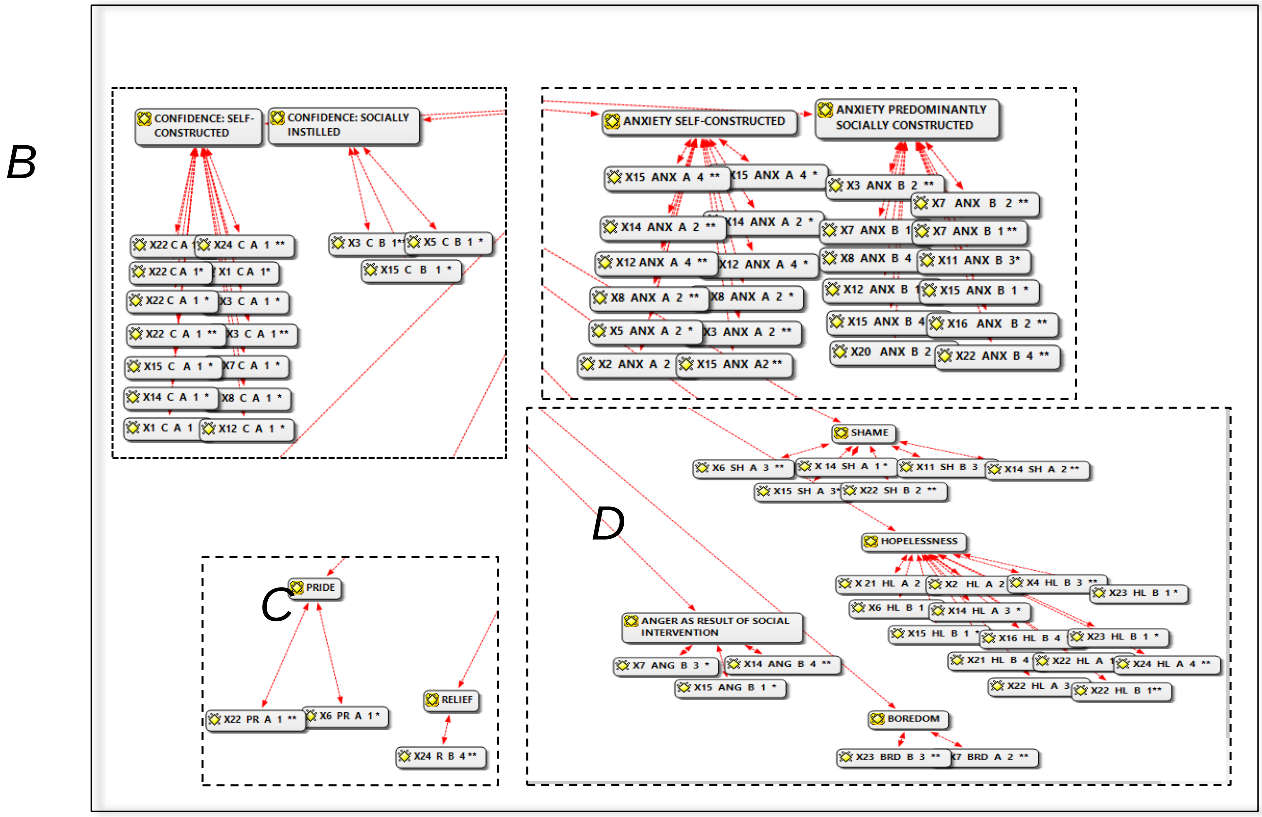


Figure 5.5. Snapshots from network view revealing Confidence (A) and Anxiety (B) construct origins, Pride and Relief (C) as well as Shame, Hopelessness, Anger and Boredom (D) as supplemental, yet complementing emotions to confidence and anxiety

This chapter will proceed by describing the research design of Phase 2B.

5.4 Research Design: Phase 2B

5.4.1 Data collection and instruments: Phase 2B

Table 5.5 orientates the reader to the description of the data instruments to follow.

Table 5.5. *Synopsis: data collection instruments: Phase 2B*

INSTRUMENT	RESEARCH SUB-QUESTION(S)	TYPE OF DATA	RATIONALE	CHAPTER SUB-SECTION
Video recordings of gameplay sessions	**RSQ 5** *To what extent, if any, do Grade 4 learners experience anxiety in CDP environments during the automatisation of multiplication facts?*	Visual/ with vocal interjections	To analyse learners' learning behaviours in both CDP and DGBL environments	5.4.1.1
Individual post-gameplay, semi-structured interviews.	**RSQ 6** *To what extent, if any, do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?*	Verbal	To elicit learners' self-reflections on gameplay sessions, emphasising gameflow experiences.	5.4.1.2

5.4.1.1 Video recordings of gameplay sessions

Three consecutive 15-minute gaming sessions (one CDP and two DGBL environments, respectively) took place. These sessions were video-recorded by means of two cameras from opposite angles to capture data on the actual gameplay throughout the sessions and to capture player's verbal attributions[17], facial expressions, posture, gestures, body movements as well as vocal interjections[18]. The video-recorded material was then edited into a dual view – synchronising player footage with game footage. This dual view (see Figure 5.6) enabled the researcher to study the two types of data (gameplay activities and bodily/facial manifestations) in relation – observing the participants' non-verbal communication in the real-time context of the game. Apart from the video-taped material, the researcher (as inside observer) also kept notes on personal observations made during the gameplay sessions. The field notes were used as auxiliary data when memos were made during the analysis process. These memos can be viewed as part of the network views displayed in Appendices H and I.

[17] **Vocal attributions** refer to players' comments (self-reflections during gameplay) in phrase or sentence format whereas…
[18] **Vocal interjections** refer to exclamations (words or sounds) used by players to express particular emotions or sentiments experienced during gameplay.

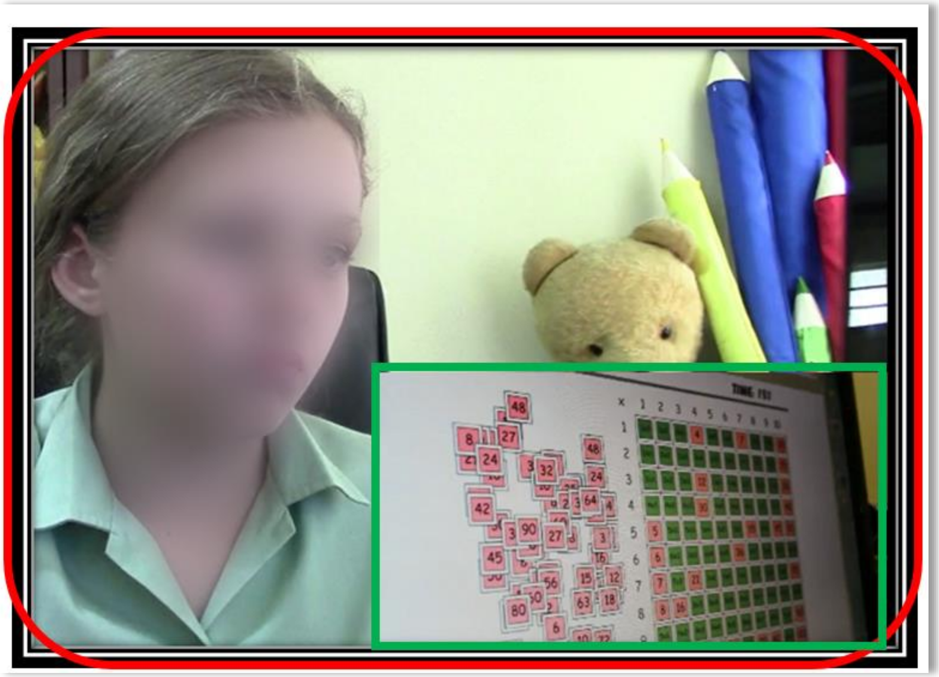


Figure 5.6. Screenshot from video-recorded gameplay (The participant's face was digitally manipulated to protect identity)

5.4.1.2 Individual post-gameplay, semi-structured interviews

The interview questions focussed on the participants' gameplay experiences within the CDP and DGBL environments and were audio recorded and transcribed *verbatim* in preparation for analysis. The following questions were used as open-ended questions to probe the participants' gaming experiences in the DGBL as opposed to CPD learning environments. The related components of Sweetser and Wyeth's (2005) GameFlow Model of Enjoyment were added to questions and printed in boldface as shown below.

- ***Immersion****: Which game did you like most? Why?*
- ***Challenge vs. player's skills****: During which game (if any) were you most stressed? Why do you think?*
- ***Control****: During which game (if any) did you feel relaxed and comfortable?*
- ***Concentration****: During which game (if any) did you feel that you could really concentrate and do your very best? Why?*
- ***Goals and feedback****: Is there a game in which you feel you could have done better? If so, what prevented you from doing your best?*
- ***Social (agent) interaction****: Which game taught you the best multiplication skills? Reason?*
- ***Control****: Do you approve of the order in which you have played the games? Why? Why not?*

The reason for using abovementioned questions to probe into the participants' gaming enjoyment in the two CAI environments, will be rendered in sub-section 5.4.3.2 on Phase 2B data analysis procedures.

5.4.2 Data collection procedures: Phase 2B

Table 5.6 outlines the data collection instruments of this phase and also outlines the data collection and analysis procedures. The data collection and analysis procedures are, however, expanded by means of Table 5.3 and described in sub-sections 5.4.2.1 to 5.4.2.2

Table 5.6. *Synopsis: data collection procedures: Phase 2B*

DATA TYPE	RESEARCH SUB-QUESTION(S)	DATA COLLECTION PROCESS	RATIONALE	SUB-SECTION
Video recordings of gameplay sessions (non-verbal data)	***RSQ 5*** *How do Grade 4 learners experience anxiety in CDP environments during the automatisation of multiplication facts?* *	Visual and auditory output: (facial expression; posture; gesture, body movement and vocal interjections)	To describe participants' gaming experiences (emphasizing *anxiety↔ confidence* experiences) through analysing visual and auditory output.	5.4.2.1
Individual post-gameplay, semi-structured interviews (verbal data)	***RSQ 6*** *How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?*	*Verbatim* transcription of audiotaped material.	To obtain participants' reflections on own gameplay experiences.	5.4.2.2

**the omitted line between RSQ 5 and RSQ 6 indicates that both the verbal and non-verbal data analysed led to answering both research sub-questions*

5.4.2.1 Collection of non-verbal data (gameplay sessions)

After the participants were identified (by eliminating the two learners with the least gameplay experience) and invited, they were introduced to the CDP game (*Smartygames*) and the two DGBL games (*Arithmemouse* and *Timez Attack*).

The actual individually scheduled gameplay sessions took place on the day following the abovementioned introductions. To exclude environmental derailing factors, learners played the games in the researcher's office where the focus group interview also took place. Participants played the games in a specific order: *Smartygames*, *Arithmemouse* and then *Timez Attack*, as the researcher anticipated that the specific order could be significant in eliciting *anxiety↔confidence* responses. The participants were afforded 15 minutes of free gameplay per game. Each subsequent session directly followed the previous session without any breaks. The researcher took on the role of inside observer, but also assisted players when they struggled to proceed due to unclear game instructions and/or faulty game mechanics.

5.4.2.2 Collection of verbal data (individual post-gameplay, semi-structured interviews)

The four participants who took part in gameplay sessions were individually interviewed by means of posing semi-structured interview questions as listed in sub-section 5.4.1.2 on the day following the gameplay sessions. The participants were interviewed in the same order that they attended gameplay sessions. Interviews took place in the researcher's office – an environment that the participants were all familiar with by that time. As counselling sessions are also conducted by the researcher in the office as part of her daily roles and responsibilities as learning support coordinator of the school, the environment was regarded as a conducive and relaxed interview environment. Although interview questions were prepared and aimed at prompting responses to gameflow and enjoyment, the interviews were still kept informal so that the researcher could resort to prompting techniques when participants only provided limited responses and did not elaborate on their answers. All sessions were audio recorded and transcribed *verbatim* afterwards.

5.4.3 Data analysis procedure: Phase 2B

5.4.3.1 Analysis of audio and visual (non-verbal) data from individual gameplay sessions

As the analysis process informed a description of respondents' gaming experiences (emphasising *anxiety↔confidence* experiences), visual and auditory output of gameplay sessions were scrutinised by means of an a-priori coding process utilising Atlas Ti software. Table 5.7 sets out these codes. In order to recap on the different facial expressions, gestures, body movements and postures associated with the academic emotions, the reader is referred back to Chapter 2, sub-section 2.4.2 and Appendix A. Once again, complimentary academic emotions were also coded for analysis. The analysis process however was limited, and probably swamped, with partially supported findings, due to two major challenges that will be outlined in sub-section 5.9.

Table 5.7. *Codes used during coding of audio and visual data from individual gameplay sessions*

Game identification		**Academic Emotions**		**Facial expressions (codes were qualified by means of short description)**		**Other bodily expressions (codes were qualified by means of short description)**		**Player identification**	
CDP Smartygames	**SG**	**confidence**	**C**	Facial muscle contractions	**FmC_**	postures	**Post**	Participant 1	**(A)**
		anxiety	**ANX**						
		enjoyment	**ENJ**	Eye movement and blinking	**Em_**	gestures	**Gest**	Participant 2	**(B)**
DGBL Arithmemouse	**AM**	**boredom**	**BRD**						
		shame	**SH**	Pupillary response	**PR_**	Body movements	**BM**	Participant 3	**(C)**
		pride	**PR**						
		relief	**R**	Head movement	**HM_**	Vocal interjections	**VI**	Participant 4	**(D)**
DGBL Timez Attack	**TA**	**hopelessness**	**HL**						
		gratitude	**GR**						
		anger	**ANG**						

Video material was viewed, re-viewed and annotated repeatedly until sufficient coding could be done to display network views on the different constructs of academic emotions and bodily expressions (by means of facial expressions, gestures, postures, body movement and vocal interjections). Figure 5.7 displays an example of a network view on facial expressions. It also illustrates the manner in which codes were allocated to a specific video frame.

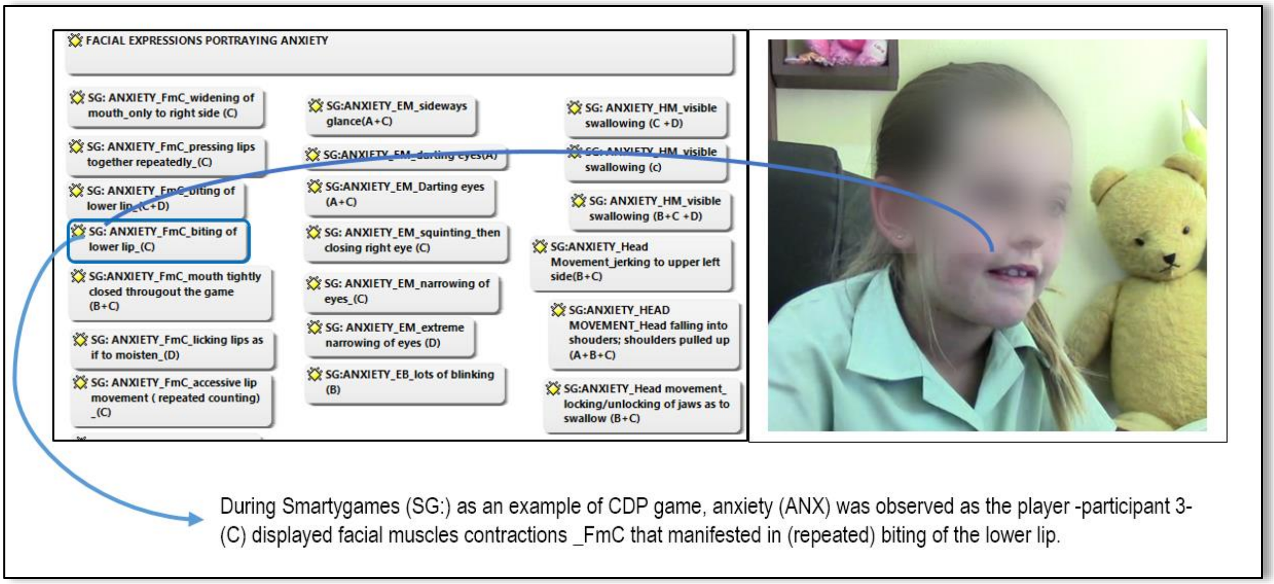


Figure 5.7. Example of a network view compiled after coding of video recordings of gameplay sessions. It also illustrates how coding of a specific video frame took place.

To enhance analysis, video material was annotated and these were saved as memos. Codes and memos were then arranged under game genre (CAI versus DGBL) to draw findings to answer research sub-questions 5 and 6 (RSQ 5 and RSQ 6). These network views are shown and discussed in Chapter 7 (sub-sections 7.3.3.1 and 7.3.4.1 as well as Figures 7.8a and 7.8b).

5.4.3.2 Analysis of audio (verbal) data from individual post- gameplay interviews

After the gameplay sessions, the researcher interviewed participants during semi-structured individual interviews to probe on their experiences of "enjoyment". Audio recordings were made of each of the four semi-structured individual interviews and transcribed *verbatim* afterwards. Coding of the focus group interview was replicated for individual interviews (Table 5.4). Over and above this analysis, Sweetser and Wyeth's (2005) GameFlow Model of Enjoyment (sub-section 5..2.4.1) enabled the categorisation of gaming experiences to establish to what extent gameflow could facilitate enjoyment, thus counteracting negative affect associated with anxiety. According to the Sweetser and Wyeth's (2005) GameFlow Model for Enjoyment, game enjoyment equals *"*deep but effortless involvement, which can often result in loss of concern for self, everyday life and an altered sense of time" (Sweetser and Wyeth, 2005, p. 10).

Should the researcher be able to obtain first person accounts of different enjoyment experiences, with respect to the different gaming environments, it would assist the interpretation of the third person (the researcher's) observation of participants' anxiety experiences during gameplay. These first person accounts enabled the researcher to distinguish between positive stress (anxiety) and negative anxiety (feelings of dread). Hackbarth, Grover and Mun (2003) differentiate between **positive** stress - *healthy anxiety*, also referred to as *excitability* and negative stress (anxiety). Where positive stress is said to occur in close contingence with a stressor, negative stress (anxiety) may also occur in the absence of the stressor. Should the lack of enjoyment in a specific game and anxious feelings be described by the participant, and observed by the researcher (as interviewer) during the post-gameplay interview, it could point to justified feelings of anxiety occurring without the stressor (playing the game) being present.

Transcriptions were read and re-read to find manifestations of the following constructs of the Sweetser and Wyeth (2005) GameFlow Model: *Concentration*, *Challenge/skills balance*, G*oals and feedback*, *Control, Immersion and Social interaction (*where the computer was viewed as the mediating agent)*.* Table 5.8 sets out these constructs.

Table 5.8. *Questions to guide analysis of leaners' gameflow experiences as expressed during individual post-gameplay interviews*

Constructs from Sweetser and Wyeth (2005) GameFlow Model.	**Paraphrasing of Sweetser and Wyeth's expansion of the constructs as to serve as questions whereby corresponding data (denying or confirming aspects of the gameflow model) could be allocated.**
CONCENTRATION	Did the game present a high work-load so that the player could concentrate on the task at hand without feeling cognitively and emotionally overwhelmed by the task?
CHALLENGE & PLAYER SKILLS	Were the learning tasks presented by the game challenging, but still perceived as enjoyable? Were the players skilled enough to execute the game mechanics, but also cognitively skilled enough to successfully complete the learning task?
CLEAR GOALS AND FEEDBACK	Did the gameplay have clear goals and had these goals been in unison with the learning goal of the game? Did players receive feedback on their progress towards both aforementioned goals?
CONTROL	Did the players feel that they were in control of the game while playing? If so, had it been due to the fact that the game provided clear two-folded goals as well as feedback regarding progress towards these goals?
SOCIAL INTERACTION	People play games to interact with other people, regardless of the task, and will even play games they do not like or even when they don't like games at all. Dis the participants experience the human-computer interaction as enjoyable?
IMMERSION	Did the players iterated on aspects that could point to players losing awareness of everyday life, losing concern about the self, or even experiencing an altered sense of time?

The abovementioned questions informed the coding of data (from the transcribed individual post-gameplay interviews) into themes denoted by Sweetser and Wyeth's (2005) gameflow constructs.

5.5 The Role of the Research Participants

An initial meeting with the six invited criterion-sampled Grade 4 girls as research participants was held. During this introductory meeting the researcher guided participants by means of the "nervous thermometer" activity towards better understanding of degrees of worry and nervousness (refer to Chapter 4, Figure 4.4 and Chapter 4, sub-section 4.3.3). Participants were each presented with an artefact that was used when indicating (by pointing to) corresponding degree of nervousness on the artefact. The participants also participated in a practice round where the use of the artefact (instead of attempting to calculate the answers) was reinforced (refer to Figure 5.2 where this artefact is depicted). Respondents did not only indicate their responses, but also responded to open-ended questions as posed by the researcher (as interviewer). Participants were informed about the audio recordings of both the group and individual interviews beforehand.

When the sample of respondents were limited to four, for gameplay sessions, the respondents were, once again, prepared for the research. After mediating the content of an informed assent form which the respondents signed, the game mechanics of the games were demonstrated and the respondents could each play for approximately 2 to 3 minutes. The researcher also briefed participants that video recordings of their gameplay sessions would take place. This did not concern them as they were used to closed circuit video cameras in their classrooms from their grade R year.

On the following day, the learners played the three different games for 15 minutes each, in three consecutive sessions. The gameplay sessions as well as the individual interviews on the following day, took place in the researcher's office at school.

5.6 The Role of the Researcher

The researcher scheduled introductory meetings with the participants and their parents/caregivers. The researcher also mediated and guided the introductory "nervous thermometer" activity with the invited participants and mediated the use of the artefact as described in the previous sub-section.

Apart from being the interviewer in both groups, as well as conducting individual interviews, the researcher also fulfilled the role of inside observer - carefully keeping anecdotal notes that were used during the data analysis. To limit the anticipated stress of gameplay sessions on the participants, by being recorded by unfamiliar technical staff, the researcher chose to record the gameplay sessions herself.

As final role, the researcher was responsible for interpretations and drawing conclusions – first to answer to the final three research sub-questions (RSQ 4, RSQ 5 and RSQ 6), and ultimately the main research question.

5.7 Triangulation

During this research phase (Phase 2), triangulation involved the careful choice of different data gathering techniques (individual and focus group interviews, as well as video recordings of gameplay sessions), each of which were to potentially reveal a different aspect of the same anxiety experiences issue under investigation. By using triangulation, the strengths of one data collection procedure (non-verbal video recorded data) can therefore compensate for the potential weaknesses of the verbal (interview) approach or *vice versa* (De Vos, 2005; Mouton, 2012). Thurmond (2001) describes the following types of triangulation relevant to Phase 2 of this study:

- *Data source triangulation* refers to the different types of data collected as described in the previous paragraph.
- *Data analysis triangulation and methodologic triangulation:* Thurmond (2001) distinguishes between across-method triangulation and within-method triangulation. Where across-method triangulation refers to both qualitative and quantitative methods used in a single study, within -method triangulation refers to the use of at least two data-collection and analysis procedures

from the same design approach. In the research design of Phase 2, data collection procedures comprised of more than two procedures: verbal and non-verbal data were analysed through similar qualitative analysis procedures. Although overlapping (for findings to converge), the clustering of data into specific pre-selected themes, differed. By combining different types of data and different methods whereby the data is collected and analysed, the researcher seek to validate the interpretations derived from the findings of Phase 2 – potentially strengthening the conclusions to follow.

5.8 Summary of the entire Research Design

The research activities during Phase 2 took place in two sequential phases (Phase 2A and 2B) during which a focus group interview, individual gameplay sessions by each of the four participants and post-gameplay individual interviews with the participants were held.

As previously stated, Phase 1's findings were sufficient as the research tools from which the research activities in Phase 2 could commence. The first research sub-question was answered during Phase 1A while the next two research questions (RSQ 2 and RSQ 3) were answered in the parallel research activities of Phase 1B.

In Phase 2A, the data collected and analysed from the focus group interview led to answering the fourth research sub-question (RSQ 4), while the gameplay and post-gameplay data analysis' findings answered the last two research sub-questions (RSQ 5 and RSQ 6). The reader is referred back to sub-section 5.1 where the last three research sub-questions were stated. At this point in time the reader is also referred back to Chapter 1, Figure 1.1 that encapsulates a holistic overview of the components of the qualitative research design across the two research phases (Phases 1A and 1B as well as Phase 2). By focusing on Phase 2 on the figure the reader will be led to a better understanding of the research processes engaged in and the rationale thereof, that enabled answering to research questions 4 to 6 respectively.

5.9 Ethical considerations

All ethical considerations pertaining to the research activities of Phase 1 (Chapter 4, sub-section 4.11) also relate to the research activities of Phase 2. In addition, the following ethical aspects were also taken into consideration.

The aim and procedures of the study was explained in the informed consent letter as well as verbally mediated to learners at their own developmental level of understanding during a briefing session preceding the study. The aspects of anonymity, confidentiality, harmless and voluntary participation and withdrawal without consequences at any point in time were mediated.

As the research participants were minors, their assent were strengthened by the informed consent of their parents/caregivers. The parents/caregivers who accompanied the participants to abovementioned briefing session, were provided with unlimited opportunity to ask clarifying questions to which the researcher responded. The researcher, at that point in time, was aware of the fact that in recording the research findings, screenshots of participants' gameplay sessions were to be used. Special permission was not obtained from parents as researcher was unaware of the fact that special permission are required even when the identities of participants are obscured by fading and blurring faces and facial expressions. When the researcher did become aware of this ethical issue when formulating Chapter 5, the parents of the final four participants were informed accordingly and requested to amend the original informed consent forms without obligation. All parents agreed and acceded to the request.

The potential benefits of the study to the entire teaching and learning community were also explained. Parents/caregivers and participants were informed upfront that only four learners would be invited to take part in the gameplay sessions. Although the qualifying criteria (most experienced game players) were explained, it raised ethical issues as the gameplay experience of the participants was reported subjectively by the respective parents/caregivers. Parents/caregivers were requested to respond to questions on the minors' computer gameplay behaviours as part of the consent form (Appendix F). They were only requested to respond by indicating the frequency of exposure to computer gameplay as 'twice or more per week', 'once a week' or 'never'.

Following Sisemore (2008), respondents (as in the pilot project) were subsequently guided through a process during which they could link the items on Sizemore's (2008) nervous thermometer to the degrees of nervousness as stated on the artefact (described in Chapter 4 sub-section 4.5.3 and depicted in Chapter 4, Figure 4.4). The artefact would be used during the pilot project focus group interview that followed. After the process of linking, participants were to cut out 'worrying about…" sentences provided and place it into appropriate bags as shown in Chapter 4, Figure 4.4 to demonstrate their understanding of the degree of nervousness.

The six participants in the focus group interview were informed about the audio recording which was being made. An age-appropriate explanation of the aim of the interview was also provided upfront by the researcher. These participants were also made aware that only four of them were to proceed to the gameplay stage and the grounds on which they were evaluated was also discussed beforehand to prevent inhibited interview responses. Before gameplay sessions commenced, participants were also made aware of the individual interviews to be conducted on their gameplay experiences on the day following the gameplay sessions.

The researcher explained to the eliminated participants why they could not continue taking part in the research study. These participants' parents were also informed by means of telephone calls, as agreed on during the information session, which was attended by both of the parents in question. The four remaining participants were invited and informed participant assent was obtained after explaining the research process, the purpose of the research and their role in executing it at their developmental level. This explanation was also put in written format (assent form) which all of the participants signed voluntarily. In addition to all ethical considerations previously explained, the process of making video recordings of the gameplay sessions were explained to the participants. The recordings could, however, inhibit participants' gameplay behaviours – influencing the findings and the trustworthiness of the study.

The researcher demonstrated the game mechanics of each game and established that everyone was capable of manoeuvring themselves through the games. This was done in such a way that the plot of the two DGBL games remained a mystery: the game mechanics were demonstrated within the opening scenes of the game and are replicated at all game levels while the opening scenes did not reveal the plot.

CDP games, however, do not present plots or storylines. Participants were labelled as learner A, B, C and D: Participants were requested to draw numbers 1, 2, 3 or 4 from a container. Number 1 then became participant A, number 2 became participant B, etc. The gameplay sessions took place in alphabetical order. The researcher was responsible for the video equipment and recordings, so that the presence of a technical assistant, that could influence participants’ gameplay behaviour, was redundant.

Research outcomes will be made available to the final four participants by means of an age-appropriate verbal explanation of how gameplay could benefit or hinder their in-class responses in terms of multiplication tables assessments (mental mathematics tests). Participants' parents/caregivers will be provided with verbal feedback on the findings and the conclusions of this study. Conclusions of the study will also be made available to the Gauteng Department of Education, as well as the school principal, in written format by means of a research report.

5.10 Challenges and Problems Encountered

Major challenges regarding the method of data analysis (non-verbal data from gameplay sessions) were encountered: As the researcher was weary about the challenges of a focus group, an artefact was designed and used (see Chapter 5, sub-section 5.3.2) to prevent the participants’ from waiting for someone else to respond first and deliberately responding in the same way as a fellow-participant. By letting the participants then (in random order) elaborate on their answers dragged out the interview beyond the concentration span of at least two participants. Sensing that, the researcher (towards the end) appointed specific participants to respond to a specific question, instead of reducing the number of questions.

To be able to analyse the non-verbal accounts accurately, baseline behaviour patterns should have been recorded for all the participants before the study commenced. Navarro and Karlins (2008) as well as Ferreira (2016) state that, although the limbic brain responds consciously or unconsciously, a possible change (threat or pleasure) to an immediate state of comfort or discomfort, a person’s psycho-physiological behaviour should be cautiously interpreted when baseline behaviour patterns are not recorded. These baseline records would enable the observer to detect idiosyncratic non-verbal behaviours (for example mannerisms) or intentional false and misleading non-verbal behaviours.

A second limitation lies in the ‘non-scientific’ manner in which the non-verbal data were analysed. When compared to the Human-Computer Interaction (HCI) software already available to interpret non-verbal indications of anxiety and other emotions, the manual coding process used in this study could be prone to many errors in interpretation. Although face muscle activity can be measured through *electromyography* (EMG), which detects the electrical discharges caused by contractions of muscle fibres, the procedures are still somewhat fallible: In Sioni and Chittaro (2015), it was confirmed that facial EMG is a valuable instrument for stress detection, but even this truly scientific method is said to display limitations in the sense of the head-mounted displays that were used to increase immersion and stress-inducing effects and covering the corrugator muscle area of the forehead where electrodes (relaying facial muscle contractions) are normally placed.

Another limitation to the research process was posed when one of the participants’ last three minutes of gameplay (of the last game round) did not video record on the screen camera. The loss of footage did not significantly impact on the quantity of data collected, as it only affected the screenplay recordings and not the player's footage.

The next two chapters (Chapters 6 and 7) reveal the research findings of the two different research phases whereas the final chapter (Chapter 8) contains a summary of the study, discussions and recommendations.

Chapter 6

Presentation of the findings: first data analysis phase

"Do not worry about your difficulties in Mathematics.
I can assure you mine are still greater."
-Albert Einstein-

6.1 Introduction

The research study follows a two-phased research design as set out in Chapter 4. The data collected and analysed during Phase 1 resulted in two sets of research instruments (adapted SEMA interview questions and appropriate CAI games) without which the second research phase could not commence. The results of Phase 1 therefore "produced" the data collection instruments for Phase 2. Chapter 6 will only reveal the research findings of the first analysis phase (Phase 1A and 1B) whereas Chapter 7 will present the findings of the second analysis phase. The reader is referred to Figure 6.1 for process tracking of the different procedures as it had been illustrated how Phases 1A and 1B "produced" the research instruments whereby the first group interview and subsequent gameplay sessions of Phase 2 could commence.

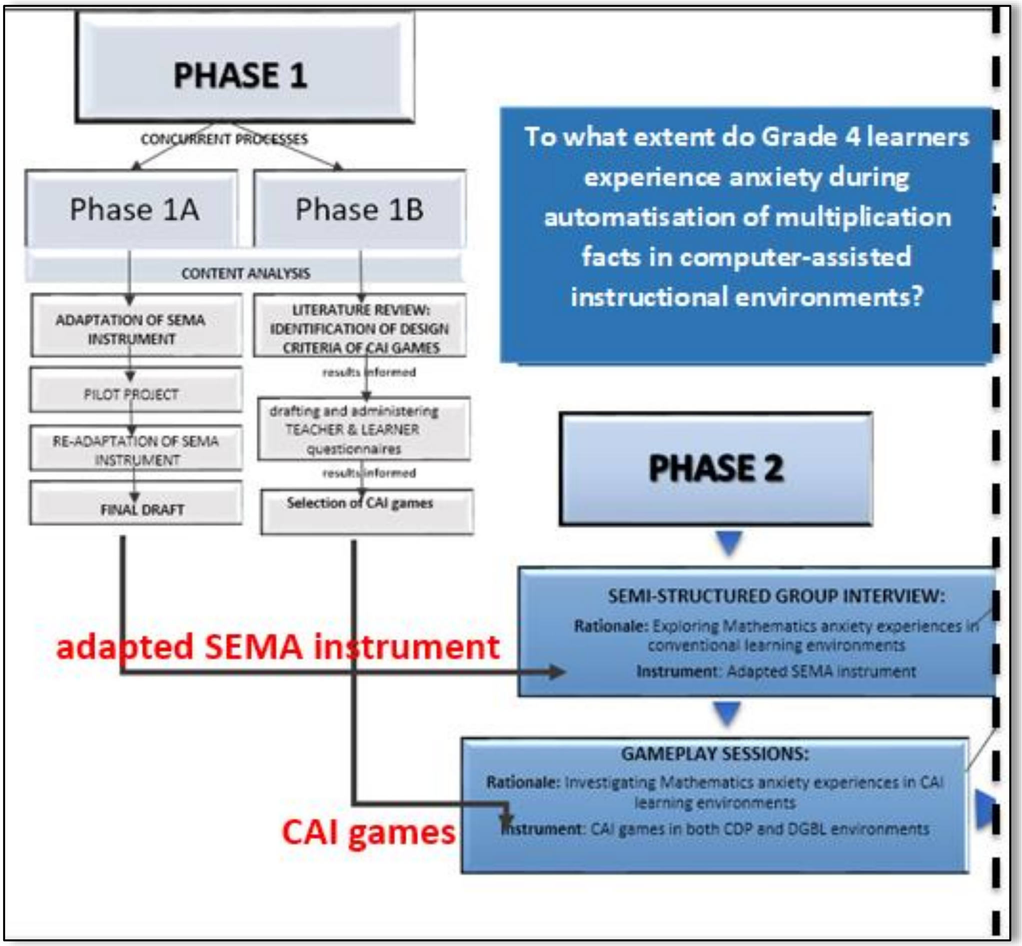


Figure 6.1. Graphic representation of Phase 1 analysis processes and procedures.

Both Phase 1A and 1B entail content analysis. In Phase 1A the researcher analysed the Wu et al. (2012) Scale for Early Math Anxiety (SEMA) as follows: first contextualising it into the South African context, then piloting and finally re-adapting it to "produce" a final draft to be used as interview statements during Phase 2. In Phase 1B, literature was reviewed to identify design criteria for CAI games. These design criteria enabled drafting of teacher and learner questionnaires to be completed by teachers and learners (respectively) as reflections of their own gameplay experiences. Teachers were requested to access the games online, to engage in gameplay and to reflect on own gameplay experiences by completing the questionnaire by providing responses (yes/no) and explanations (reasons for the particular yes/no response)[19].

Figure 6.1 therefore only highlights how the "products" of Phase 1 (adapted SEMA instrument and appropriate CAI game in CDP and DGBL domain respectively) became the pre-requisite research instruments for Phase 2. The broken line used on the right-hand side of the figure indicates that only a portion of Phase 2 is revealed.

Table 6.1, containing research sub-questions informing Phase 1 investigations and the corresponding chapter sections, reveal the results and findings as follows:

Table 6.1. *Research sub-questions informing Phase 1 investigations and the corresponding chapter sections revealing the results and findings thereof*

Research sub-questions	Content: research sub-questions	Relevant chapter sections
1	*What is the conceptual value of adapting the SEMA instrument with regard to the methodology of the study?*	6.2.1
2	*What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?*	6.2.2 (recapping content analysis results -chapter 3)
3	*Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?*	6.4.1- 6.4.3

The aim of Phase 1 was two-fold: to prepare (by adapting the SEMA instrument) a set of interview questions by which a group interview in Phase 2 (answering to RSQ 1) could be conducted and to reveal an appropriate game in both CDP and DGBL environments that could be used in gameplay sessions in Phase 2 (answering to RSQ 2 and RSQ 3). This chapter will commence by recapping the results of Phase 1A as it involved a pilot project and the results already revealed in Chapter 4 were imminent to describing the entire research design.

[19] Refer to teacher questionnaire- Addendum C.

6.2 Recapping Results of Phase 1A

6.2.1 Recapping on answering to Research sub-question 1: What is the conceptual value of adapting the SEMA instrument with regard to the methodology of the study?

After contextualising the Wu et al*.* (2012) Scale for Early Math Anxiety (SEMA) to be more compliant to the South African context (aligning it to context of the South African Mathematics curriculum and cultural contexts), the adapted instrument was piloted with six grade 4 learners to determine which instrument statements would elicit more spontaneous responses. The number of statements on the SEMA instrument had to be reduced to fulfil the purpose of interview statements in the second research phase. (Refer to Chapter 4, sub-section 4.3.3). Therefore the items that elicited more spontaneous responses were kept and the final adapted instrument consisted of 11 statements. These statements were used as interview questions for collecting qualitative data (and not as statements for collecting only quantitative data as in the original instrument) during the group interview conducted in Phase 2. Open-ended prompts were also added to each statement to make it even more conducive for collecting *qualitative* data (Leedy & Ormrod, 2010). The final draft of the adapted SEMA instrument emerged as the research result. The reader is referred to Chapter 4, Table 4.3 where the final draft of the SEMA instrument can be accessed. The rest of this chapter will reveal the results and findings of Phase 1B, exposing the procedures by which the initial sample of possible games were analysed and how, through a process of elimination, the most suitable games for the Phase 2 gameplay sessions were identified.

6.2.2 Recapping on answering to research sub-question 2: What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments?

Through the content analysis in Chapter 3, seven game design criteria that would determine the differences in the quality of educational games could be identified as: *game context, situational interest (sensory stimuli, curiosity and mystery; fantasy; gender differences), rule and goal structure, interactivity, challenge, immersion (engagement, engrossment and total immersion) and feedback (reflection, transfer and automaticity).*

Ahmad et al. (2015), however, cautions game assessors that the effectiveness of a game do not lie in the success of individual design elements, but rather in the relationships and coalition between the different design criteria.

6.3 Conceptual Framework for Analysis of Data Captured during Phase 1B

The conceptual framework against which the analysis of the entire study was done, was discussed in Chapter 2 (Figure 2.2). Figure 6.2 below replicates that of Chapter 2, but *in addition*, it also focuses the reader to the specific conceptual framework against which the analysis of Phase 1B was undertaken. Research sub-questions 2 and 3 require investigation into the game design criteria that foster gameflow and ultimately automaticity regarding multiplication skills. To analyse the game samples, both Song and Zhang's (2008) EFM model and the GameFlow model of Sweetser and Wyeth (2005) were utilised as conceptual frameworks.

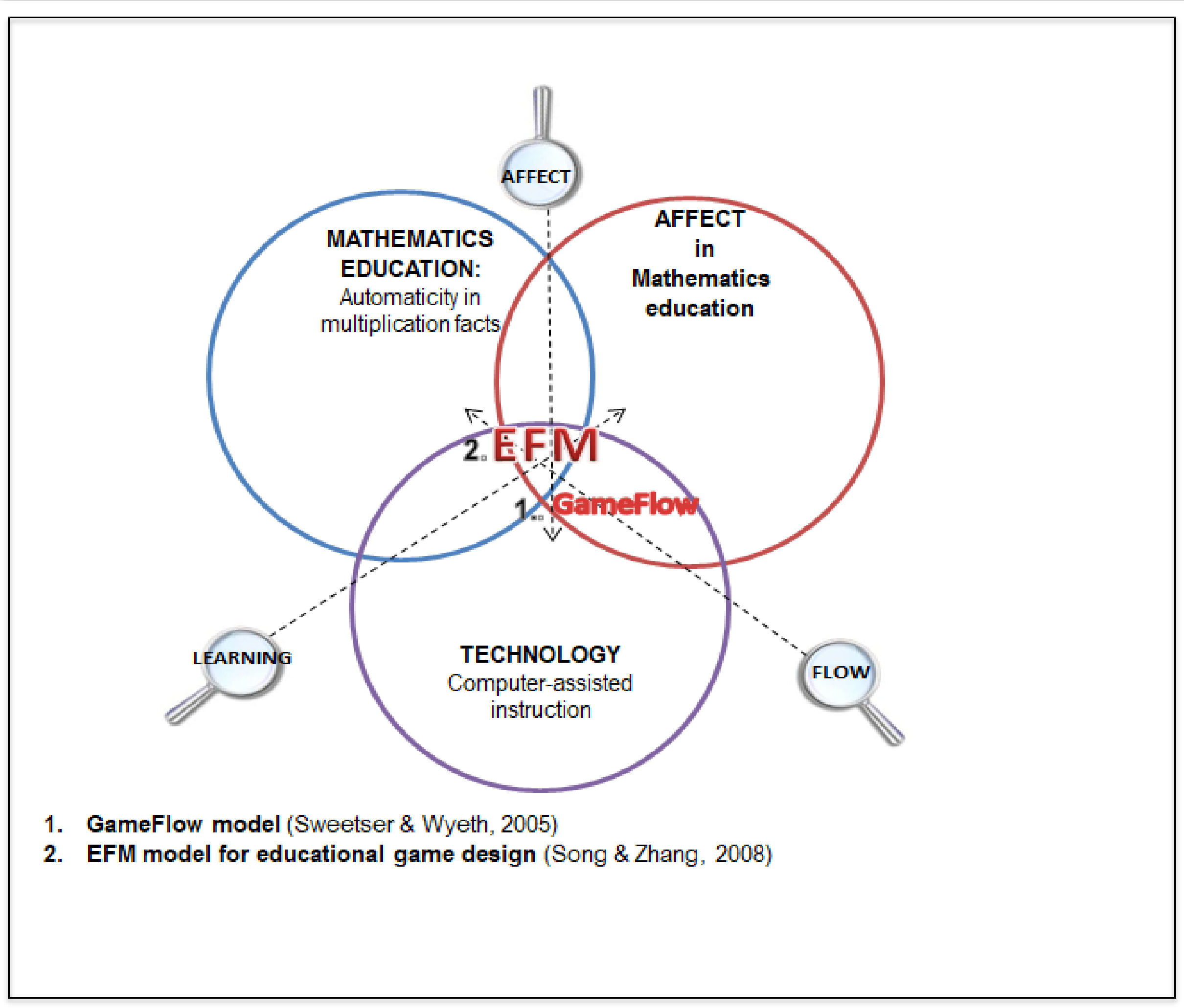


Figure 6.2. Conceptual framework against which analysis of Phase 1B took place - indicating the focal areas (1 & 2)

Figure 6.2 outlines the interrelatedness of the three major disciplinary fields within which the research was conducted: Mathematics education, affect in Mathematics education and Technology (CAI). It also illustrates how the research problem was viewed through the overlap of the lenses of learning, affect and motivation respectively. The aim of this figure is, however, to draw the reader's attention to the two different models (EFM model and Gameflow model) that form part of the conceptual framework for analysing the games samples. Through integrating these two models with the design criteria revealed through the content analysis in Chapter 3, the conceptual framework that could be applied in analysing the data collected in Phase 1B emerged (Figure 6.3). The purpose of the combined framework as displayed in Figure 6.3 and Table 6.2 served as criteria whereby the initial six purposively selected multiplication games could be narrowed down to a single game in both the CDP and DGBL environments. The design criteria of these games would interact in such a way that it optimally motivates players to pursue the game goal, but simultaneously and subconsciously also reinforce the learning goal (automatisation of multiplication facts) as the game goal cannot be attained without mastering the learning goal.

The different components of the combined conceptual framework will henceforward be discussed. The EFM model of Song and Zhang (2008) puts a comprehensive model for educational game design forward while the GameFlow model of Sweetser and Wyeth (2005) exposes a set of questions on all design criteria of CAI games that emerged from the literature study in Chapter 3 (Table 3.2). It therefore follows that *game design criteria* are the linking concept in all of the three different constructs. In the framework (Figure 6.3) corresponding colours are used to illustrate the inter-relatedness between Song and Zhang's (2008) constructs and Sweetser and Wyeth's (2005) GameFlow model. To illustrate this, the black arrow connects the design criteria of immersion (colour-coded green) to the relevant green sections of the flow dimensions of Song and Zhang's (2008) model. To connect all the associated constructs by means of lines, would visually pollute the framework. To provide clarity, Table 6.2 presents only the colour-codes constructs of Figure 6.3. The reader can therefore make use of colour correspondence as in Figure 6.3 or alternatively refer to the tabled format (Table 6.2) on how identified game criteria as revealed by means of content analysis (Chapter 3) are represented in Song and Zhang's (2008) EFM model for educational game design. In the text, Table 6.2 is displayed directly after Figure 6.3.

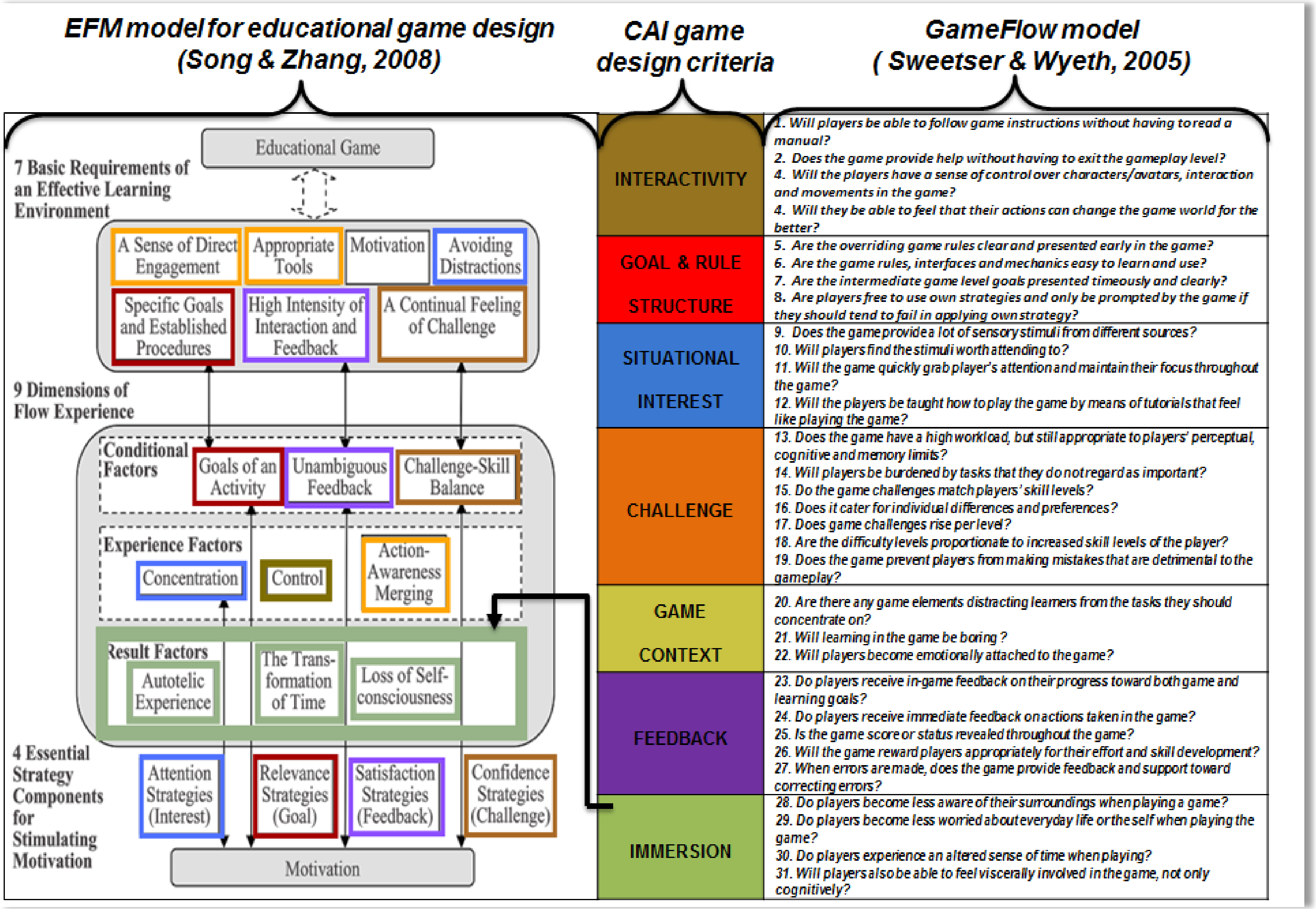


Figure 6.3. Expansion of the focal areas indicated in Figure 6.2: the corresponding colours explain the synergy between the design criteria and constructs of Song and Zhang's (2008) EFM model.

Table 6.2. *The interrelatedness between game criteria and elements of educational game design as found Song and Zhang's (2008) EFM model*

Elements of educational game design (and the sub-division thereof) according to Song and Zhang's (2008) EFM model		CAI game design Criteria (Chapter 3)						
		INTERACTIVITY	GOAL & RULE STRUCTURE	SITUATIONAL INTEREST	CHALLENGE	GAME CONTEXT	FEEDBACK	IMMERSION
BASIC REQUIREMENTS FOR EFFECTIVE LEARNING ENVIRONMENTS	SENSE OF DIRECT ENGAGEMENT	✓						
	APPROPRIATE TOOLS FOR THE TASK AND USER	✓		✓		✓		
	SPECIFIC GOALS & ESTABLISHED PROCEDURES		✓					
	CONTINUAL FEELING OF CHALLENGE				✓			
	AVOIDING DISTRACTIONS			✓				✓
	HIGH INTENSITY OF INTERACTION AND FEEDBACK			✓			✓	
	MOTIVATION					✓		
DIMENSIONS OF FLOW EXPERIENCE	GOALS OF ACTIVITY		✓					
	UNAMBIGUOUS FEEDBACK						✓	
	CHALLENGE –SKILLS BALANCE				✓			
	CONCENTRATION			✓				
	CONTROL	✓						
	ACTION-AWARENESS MERGING							✓
	RESULT FACTORS autotelic experience							✓
	transformation of time							✓
	loss of self-consciousness							✓
STRATEGIES FOR SIMULATING MOTIVATION	ATTENTION STRATEGIES (INTEREST)			✓				
	RELEVANCE STRATEGIES (GOAL)		✓					
	SATISFACTION STRATEGIES (FEEDBACK)						✓	
	CONFIDENCE STRATEGIES (CHALLENGE)				✓			

✓ represents the interrelatedness between different game criteria and specific elements of educational game design as found Song and Zhang's (2008) EFM model

The seven fundamental CAI game design criteria (as revealed through the content analysis in the literature review of Chapter 3) are central to this framework (Figure 6.3). On the right hand side of the framework, the link between these seven design criteria and Sweetser and Wyeth's (2005) GameFlow model is displayed. This Gameflow model consists of 31 requirements for gameflow that are presented as questions linked to each of the different design criteria (for example questions 1 to 4, for example, are connected to *interactivity;* questions 5 to 8 on *goal and rule structure*). Each of these sets of questions are also related to Csikszentmihalyi's (1990) nine *flow experience dimensions* as represented by the corresponding colours of design criteria (centre) and flow elements (left). Questions on all design criteria except those pertaining to *immersion* could be linked to the seven basic requirements of effective learning environments as contained in the EFM model (Song & Zhang, 2008). The EFM model's strategy for stimulating motivation (attention or interest; relevance or goal, satisfaction as well as confidence strategies) are linked by Song and Zhang (2008) to game design criteria of situational interest, rule and goal structure, feedback and challenge respectively. On the left hand side of the framework is Song and Zhang's (2008) model for educational game design which consists of three interrelated sections: the seven basic requirements for effective learning environments, the nine dimensions of flow experience derived from Csikszentmihalyi's (1990) elements of flow, and the four essential components for stimulating motivation derived from Keller's ARCS model (1987). ARCS refer to ***A****ttention* strategies (for arousing and sustaining learners' curiosity and interest), ***R****elevance* strategies (that link to learners' needs, interests, and motives), ***C****onfidence* strategies (that help learners develop success expectations) and ***S****atisfaction* strategies (providing extrinsic and intrinsic reinforcement for learner effort).

Table 6.2 shows the three interrelated sections of Song and Zhang's (2008) EFM model (as set out in the previous paragraph) which can be associated with the design criteria revealed by means of the content analysis in Chapter 3. Each of the seven basic requirements for effective learning environments, the nine dimensions of flow experience and the four essential components for stimulating motivation contain a description of one or more of the design criteria of educational games. The reader is referred back to Chapter 3, sub-section 3.2 in which Song and Zhang's (2008) criteria for educational games are reflected in the description of the design criteria of educational games as revealed by means of literary content analysis. For example: *challenge* (as design criteria) can be positively linked to Song and Zhang's "continual feeling of challenge" as players should continuously be exposed to learning activities that lie just outside of their skill level at the time (Shin et al., 2012). *Challenge* can also be associated with Song and Zhang's (2008) concept of "challenge -skills balance" as the cognitive challenges within the game can easily exceed the learners' working memory capacity to process the auditory, textual or visual stimuli embedded in the game design (Mayer & Moreno, 2003). This imbalance can prevent gameflow. In this regard a game can be regarded as pleasingly challenging due to attractive interface design criteria. Due to this, the player is motivated to pursue the game goal; should the learning challenges in the game (for example problem solving in Mathematics) however exceed the skill level of the player, gameflow will come to a halt. Song and Zhang (2008) therefore view *challenge* as the core motivational element of games: once a learner experiences challenge as positive, he/she will gain "confidence" to proceed in the game.

Based on the conceptual framework (Figure 6.2), educational games can be regarded as learning environments. Song and Zhang (2008) however emphasise that for games to be classified as *effective* learning environments, the educational games need to optimally comply with prerequisites of an effective learning environment especially in creating flow experiences to inspire motivation, and in turn, ultimately improve the quality of learning. In order to be regarded as a conducive CAI game, a game would therefore need to comply optimally with the framework set out in Figure 6.3 and Table 6.2. Not only does a game need to display *all design criteria* but it needs to comply with *all elements of each specific criteria* to create gameflow and ultimately motivate the player to not only return to the game for the sake of playing, but also for the sake of learning (Wouters et al., 2013).

The 31 questions on the right hand side of the conceptual framework (Figure 6.3) were applied as questions on the data collection instruments distributed in Phase 1B, namely teachers questionnaires (that consisted of questions 1 to 27 of Sweetser and Wyeth's (2005) GameFlow model) (N = 5) and learner questionnaires covering the remainder of the questions (questions 28 to 31) (N = 24). The remainder of this chapter sets out the analysis and results from the data collected by means of these teacher and learner questionnaires.

6.4 Analysis and Results of Phase 1B Data Collection: Teacher and Learner Questionnaires

The teachers' questionnaires consisted of either positive or negative responses to individual questions on their own gameplay experiences. The questions covered all design criteria: *game context, situational interest, rule and goal structure, challenge and interactivity* as posed by Sweetser and Wyeth (2005). Teachers were also requested to comment on their responses by explaining their positive or negative responses. Data from learner questionnaires only contained positive or negative responses to questions on *immersion* (the remaining design element).

All of the teachers (n=5) completed the optional "comments" column as well. Questionnaires were received and completed by twenty four learners. Learners (n=24) were not required to comment on their responses by providing reasons for positive or negative responses. Table 6.3 displays the number of positive teacher responses in relation to the total number of positive responses that could be obtained per criteria per game. The tabulated results are set out according to game classification (CDP or DGBL) and genre (drilled exercises, adventure games or 3D-adventure games) as well as the design criteria – the central constructs of the theoretical framework (Figure 6.3 and Table 6.2).

Table 6.3. *Total number of positive responses on game design criteria as indicated by means of completed teacher and learner questionnaire items*

		*maximum number of positive responses	Computer drill and practice (CDP) games		Digital Game-based learning (DGBL)games			
					Adventure games		3D-Adventure games	
			SG (Smarty-games)	MD (Multipli - cation Drill)	FS (Fish Shop)	GPP (Grand Prix Pro)	Am (Arithme-mouse)	TA (Timez Attack)
TEACHER QUESTIONNAIRES (refer to Appendix C for example)	INTERACTIVITY (Q1-Q4)	20	5	4	8	9	20	20
	GOAL & RULE STRUCTURE Q5-Q8	20	4	9	15	15	18	20
	SITUATIONAL INTEREST Q9-Q12	20	0	0	9	9	16	20
	CHALLENGE Q13-Q19	35	13	12	7	7	26	32
	GAME CONTEXT Q20-Q22	15	0	0	8	7	15	14
	FEEDBACK Q23-Q27	25	14	12	13	14	21	20
LEARNER QUESTIONNAIRES (refer to Appendix D for example)	IMMERSION Q1-Q5 (10 boys)	50	0	0	1	12	10	45
	IMMERSION Q1-Q5 (14 girls)	70	0	0	21	4	70	28

*MAXIMUM NUMBER OF POSITIVE RESPONSES refers to the number of questions (Q) multiplied by the number of respondents

These results will be discussed according to game classification and genre – focussing on the extent the respective games were able to represent the design criteria of effective games as depicted by the conceptual framework. To summarise the results within each game genre, the overall compatibility with Song and Zhang's (2008) EFM model for educational game design is discussed.

6.4.1 Computer drill-and-practice (CDP) games: Smartygames (Sg) (Puzzle game) and Multiplication Drill (MD) (Quiz game)

Teacher and learner responses as well as teachers' explanations of their own positive or negative responses to questions were studied to determine whether Sg an MD display all of the design criteria central to the theoretical framework (Figure 6.3 and Table 6.2). The results are presented under individual game criteria as revealed in sub-section 5.3 and listed in Figure 6.3.

6.4.1.1 To what extent do Smartygames (Sg) and/or Multiplication Drill (MD) represent the identified design criteria of effective games?

- *Interactivity*

Interactivity is defined as iterative two-way actions (*interactivity*) between the player and the game context (*direct engagement)* in which both parties are allowed to make meaningful contributions towards the outcomes of the game (*control*) (Gunter et al., 2007). To be classified as *interactive*, games should create *a sense of direct engagement* and *control* in and over the game. Although both games were not thought to be regarded as *interact*ive (4 and 5 possible responses from a possible 20), Sg received one more positive response than MD. Upon investigating the individual components for a game being rated as interactive, the difference could be explained.

With regard to *a sense of direct engagement* and *control* in and over the game, teachers found that learners would be able to play both Sg and MD without any instructions – which could lead to feelings of being 'in control' of the game. No avatars that could provide direct engagement safe educational environment (Faiola et al., 2013) were however found in both games. With respect to MD, no controlling sub-elements of interactivity namely dialoguing and searching (refer to Chapter 3, sub-section 3.2.4), that could lead to independent navigating through the game, could be established.

Regarding Sg, *somewhat* control in terms of independent searching and navigating was noticed. MD provided less control than Sg as the game only allows for 'typing answers'. In the end it only sums up the number of correct responses, it excludes the incorrect answers. The extent of control in Sg did, however, not result in feedback or gameflow changes as in the case with games with high levels of interactivity (Whitton, 2010). This theme will be explored in full under the heading of "feedback" below. Whitton (2010) reminds us that when the player's unique actions in a game does not lead to further changes in the game itself or generate individualised feedback from the game, it cannot be considered interactive. Although the data revealed that Sg offered more opportunities for independent searching (labelled by Whitton as unique gaming actions), neither of the games comply with interactivity as game criteria due to the lack of a true sense of engagement and control over the game. Without control in and over the game, no gameflow could be present according to the EFM model for educational game design (Song & Zhang, 2008).

- *Goal and rule structure*

To comply with this design criterion, games need to display a smooth and flexible rule and goal structure that could facilitate gameflow. All teachers (*n*=5), however, found that both games were inflexible with a rigid rule and goal structure as no levels or stages but only rounds with same difficulty levels were presented [QW[3]] [QV[5]][20]. Teachers responded more positively to MD than Sg due to the following factors:

A major derailing factor that resulted in Sg being rated lower than MD was the *drag-and-drop-action* to move an answer from the list next to the play board answer onto the play board that was not explained upfront – players contested that they wasted time by figuring this out by themselves. [QV[5]]. Players were

[20] Reference to teachers' explanations of their own responses. QV[5] for example refers to the fifth explanation of teacher V.

also not "*warned upfront that wrong answers will be 'returned' to the pile of possible answers"* [QW[3]]. Sg was also disregarded due to the confusion of too many sums- "all a big mess"- that needed to be figured out without proper instructions and game rules [QX[5]].

On the positive side, the rigidity of the rule structure in both games prevented tedious explanations of rules that, according to Song and Zhang (2008), could have consumed players' cognitive resources and possibly prevent flow experience. Flow experience was, however, already hindered in both games by failing to clearly describe the integrated learning and gaming goal. This aspect forms an integral part of Song and Zhang's (2008) EFM model.

- *Situational interest*

The design criteria of situational interest is met when games contain elements of sensory stimulation, curiosity, fantasy and/or mystery. Plass et al. (2013) assert that by raising situational interest in-game distractions can be avoided to ensure optimal levels of player concentration. None of the teachers found any of the CDP games to contain elements of sensory stimulation, curiosity, fantasy or mystery that would avoid distractions, keep learners on task and interested. Only negative responses were received which had been explained by for example "*Experienced gamers will not be fascinated by MD and SG"* [QY[6]].

- *Challenge*

Optimal levels of *challenge* within a game are created by means of *continual feeling of challenge, while simultaneously, maintaining a balance between challenge and skills* (Song & Zhang, 2008). With regard to this aspect the following were found: The timed-drill aspect of both games could be instilling fear in learners that could leave them over-challenged: "*Drill games are too strenuous – especially for those who struggle against time. Cannot think that a 10-year-old will agree to speed drill tests being important. Do not think that 10-year-old should be in pressure pot against time as I think it may instil fear"* [QY[9]]. Sg was found to be beyond the curriculum expectations of learners at beginning of grade 4 as it expected all times tables to be included in mental mathematics exercises " *cognitive load **too high** (mental mathematics gr 4 only up to 10X10)"* [QV[11]]. All the teachers responded unanimously that there was no chance of players being declared competent before the end of the game – they would therefore not feel able to perform before the end of the game.

The positive response discrepancy in the favour of Smartygames can be attributed to the "*… non-invasive way of SG, but I admit that it can be confusing when learner does struggle"* [QX[13]]. Sg therefore appears more *game-lik*e and less *textbook-like* and could therefore ensure a more pleasant or motivating challenge than MD. Mayer and Moreno (2003) argue that apart from the difficulty levels of the learning content of the game, the cognitive challenges within the game can easily exceed the learners' working memory capacity to process the auditory, textual or visual stimuli embedded in the game design. Cognitive overload occurs thus impairing a player's ability to process the essential information vital to fulfilling the game and learning goals. In both games, no gaming aspects causing extraneous distractions resulting in working memory overload could be found. Everything is only about math; it "*focuses learner on the task at hand, no external distractors within the game"* [QV[16]].

- *Game context*

Devlin (2013) contests that an intriguing game context could counteract the negative and devastating effect of rote learning methods (memorising through repetition) that tend to prevail when teaching and learning basic computational skills in classroom contexts. Gameplay can provide similar repetitive practice, but learners will remain intrinsically motivated as they remain focussed on the game goal, plot and storyline and not the educational goal of memorising the bonds. Teachers unanimously reflected on the absence of an intriguing plot. Automatisation was only facilitated by means of rote memory. "*No plotline*" or storyline existed and all game activities were only focussed on "*drill and practice*" [QY[13]].

- *Feedback*

Feedback can be perceived as an umbrella construct, incorporating *reflection*, *transfer* and *automaticity* (Huang et al., 2013). In order to fully comply with reflection, reflection should entail individualised error analysis and remedial intervention. The positive teacher responses on *feedback* as game design criteria only stemmed from the fact that *feedback* (correct or incorrect) is provided – "*only about right or wrong*" [QW[17]]. The difference between positive responses regarding Sg and MD in favour of Sg, could stem from the fact that Sg provided immediate feedback whereas MD provided delayed feedback – only at the end of a round. Sg provided opportunities for reflection by rejecting incorrect answers, no prompts that could be regarded as corrective feedback were detected [QX[19]]. As reflection precedes transfer and automaticity, it can be inferred that none of these games did comply with *feedback* as design criteria.

- *Immersion*

Brown and Cairns (2004) claim that immersion relates to the highest degree of engagement in and within a game – players first become engaged (engagement *with* a game), then engrossed and finally immersed (latter two terms point to engagement *within* the game when already engaged in the game). Learners had to answer questions relating to the extent that they would possibly become involved in the two games. No learner indicated any possibility of becoming *engaged* in either of the games – therefore negating the possibility of becoming engrossed and eventually immersed.

6.4.1.2 To what extent do Smartygames (Sg) and/or Multiplication Drill (MD) demonstrate the criteria for effective CAI games?

To determine whether the CDP games can be regarded as good educational (CAI) games, teacher and learner responses were also scrutinised to reveal the games' compliance with Song and Zhang's (2008) EFM model for effective educational games. The compliancy results will be presented under the three different aspects of the model (Effective learning environment, Flow dimensions and Motivational aspects).

- *Requirements for effective learning environments*

Do Sg and MD display the basic requirements for effective learning environments as displayed in Table 6.1? Teachers' explanations of their own positive and negative responses were used as data. These requirements were changed into question format to enable matching of teachers' explanations to the relevant requirement(s). To display the results and interpretations more effectively, a tabled format

(Table 6.4) was used to pair the 7 requirements of effective CAI learning environments (Song & Zhang, 2008) with relevant teacher explanations of their own positive or negative responses to specific questions.

Table 6.4. *Teachers' comments (explanations of positive or negative responses) organised according to criteria for creating an effective learning environment by means of CDP games (Sg and MD)*

Song and Zhang's (2008) criteria for creating effective learning environments.	Relevant teacher explanations
Does the game provide a high intensity of interaction and feedback?	*"All games are rewarding.* The question of whether a 10-year-old can be motivated by intrinsic rewards, however remains."[QV33] "The score keeping could negatively influence struggling learner (first 4 games). Reality (multiplication) will kick in, instead of getting carried away by the game and practice multiplication that way." [QX19]
Does the game set specific goals and established procedures?	"MD: rigid game structure hindering gameflow." [QX6] "Die drag-and-drop action utilised in Sg will most probably needed to be explained to players." [QV5] "I had trouble to figuring out SG mouse action. They should warn you about the "returning of wrong answers." [QW4] "Die mechanics of MD is so boring it is actually confusing – probably due to the fact that one does not really concentrate. SG: the entire game is one merry mix up – no levels or stages."[QX5]
Does the game motivate learners towards attaining learning goal?	"Sg and MD no plot, drill games." [QY13] "The timer distracting play – too prominent (Sg)."[QW13]
Does the game provide a continual feeling of challenge that is neither so difficult as to create a sense of hopelessness and frustration, nor so easy as to produce boredom?	"Sg: cognitive load too high (mental mathematics gr 4 only up to 10X10)." [QV11] "In first two games, everything is about math." [QW9] "Drill games are too strenuous – especially for those who struggle to work against time. Cannot think that a 10-year-old will agree to speed drill tests being important. Do not think that 10-year-old should be in pressure pot against time as I think it may instil fear". [QY9] "Uncalled for drilling against time. Learner that is already fearful will start struggling even more."(Sg & MD) [QX13]
Does the game provide a sense of direct engagement?	"Cannot imagine that learners will even have a remote sense of control over Sg and MD." [QV1] "No control: Sg and MD= correct responses are all that matters." [QY2]
Does the game provide appropriate tools that fit the user and task so well that he can get aid and do not distract?	"Only a task orientated teacher will be elated by the success rate (high scores)." (Sg) [QX15]
Does the game avoid distractions and disruptions that intervene and destroy the subjective experience?	*"Approve of non-invasive way of SG (returning of wrong answers*), but admit that it can be confusing when learner does struggle."[QY12]

The first column sets out the criteria for creating an effective learning environment in question format. The second column represents the teachers' explanations relevant to their own positive or negative responses to specific questions. Although teachers' explanations focussed on design criteria, the framework set in Table 6.2, directed the researcher to connect teachers' explanations to Song and Zhang's (2008) specific questions on effective learning environments. The explanations pertaining to *positive* responses are indicated in italics in Table 6.4 above.

There were many negative responses and teachers unanimously stated that neither Sg nor MD managed to set specific goals and established procedures. According to the teachers these games do not harness the potential to motivate learners towards attaining the learning goal and neither could Sg nor MD provide a continual feeling of challenge to the player- the game being either too difficult (and created a sense of hopelessness and frustration) or too easy (causing boredom). Furthermore, neither of the games could provide a sense of direct engagement in pursuing the goal that would lead to attaining the learning goal.

Teachers, however, did comment on the fact that ten-year olds *could possibly* respond positively to intrinsic rewards (high game scores) [QV[33]] and that teachers would then wrongfully associate high scores in the Sg time-drilled exercise with the mastering of times tables [QX[15]]. It can be inferred that Sg and MD could adhere to the criteria of high levels of interactivity and feedback, and limiting distractions that could lead to focussing on the learning goal. One teacher regarded Sg's method of returning incorrect answers instead of marking it wrong (using an x) in MD as positive, but also acknowledged the fact that the very same game action could derail struggling learners.

- *Dimensions of Flow experiences*

Song and Zhang (2008) grounded their framework on flow theory as shown by Csikszentmihalyi (1990). They categorised Csikszentmihalyi's flow elements into three sub-groups: conditional factors, experience factors and result factors as indicated in the second column of Table 6.4. Teachers' explanations will also be revealed by means of this categorisation to determine whether Sg and/or MD could potentially induce flow experiences on the part of players.

- Conditional factors

From analysis in the sub-section 6.4.1.1 as well as the current sub-section it has been concluded that both Sg and MD display a *rigid* rule and goal structure which is counter-productive to creating gameflow. Garris et al. (2002) and Shin et al. (2012) stress the fact that although rules may be known beforehand, *how* the game will play out needs to remain unpredictable. If not (as in the case with Sg and MD) the gameflow is interrupted. Previous analysis results also point to the type of feedback provided in both Sg and MD (Ke, 2008). Sg was found to be less intrusive than that of MD, but still no *informative*, *corrective* feedback could be found. Without corrective feedback, players fail to be completely in control of the game. Without control, transfer of attained skills cannot be optimised as the player will not be motivated to repeatedly return to the game to practice skills (Paras & Bizzocchi, 2005).

In both games, teachers' responses and explanations pointed to the skill-level being too high for 10-year-old players resulting in players feeling over-challenged due to cognitive overload ([QX[19]], [QW[13]], [QV[11]], [QW[9]], [QY[9]] and [QX[13]]). As conditional factor, the imbalance between challenge and skill can be regarded as the major factor derailing gameflow – eventually preventing transfer and automaticity of the attained knowledge and skills throughout the game (refer to Chapter 3, sub-section 3.2.7).

- Experience factors

It has already been inferred that players of both Sg and MD are at risk of not having control over the game. Furthermore teachers commented that players need to be fully competent in order to advance in the game and unsuccessful or partially successful players will soon lose concentration ([QX[19]], [QW[9]], [QY[2]] and [QY[12]]). In sub-section 6.4.1.1 both games' inability to raise situational interest was highlighted. As situational interest motivates the player to concentrate on the game goal (and indirectly on the learning goal as well), lack of attention strategies can hinder gameflow (Ghani et al., 1991; Gunter et al., 2007). This loss of control together with lack of strategies to keep players' concentration levels at optimal levels result in separation between action and awareness, inhibiting the player to reach a state of deep and effortless involvement in the game (Csikszentmihalyi,1990; Sweetser & Wyeth, 2005).

- Result factors

Learners' responses on immersion provided data for determining whether Sg and MD would hold the potential to induce autotelic experiences (refer to Chapter 2, footnote 4), transformations of sense of time and loss of self-consciousness. As none of the respondents indicated that they would possibly become immersed in any of the two games, Sg and MD fail to demonstrate result factors crucial to creating gameflow. Immersion is viewed as a pre-requisite for the ultimate attainment of game goals and it also promotes achieving learning goals (Ermi & Mäyrä, 2005; Ijsselsteijn et al., 2007).

- *Strategies for stimulating motivation*

Keller's ARCS model (1987) and Song and Zhang (2008) emphasise that to elicit, inspire and maintain motivation is the first step towards the design of environments that are conducive to learning. The game design criteria focusing on motivation are attention (situational interest), relevance strategies (flexible goal and rule structure), satisfaction strategies (feedback) and confidence strategies (challenge – skills balance).

All of these requirements were already discussed in the current and previous sub-sections. It would therefore suffice to state that Sg and MD do not stimulate motivation due to the lack of attentional strategies (plot, sensory stimulation, curiosity, fantasy and/or mystery elements) "*In first two games, everything is about math*" [QW[9]]. Furthermore, the imbalance between challenge and the players' skill levels inhibits in-game feedback of feeling confident before declared competent (Gee, 2007; Shin et al., 2012; Whitton, 2010). Together with the rigid rule and structure that Sg and MD display, the degree to which these games can create feelings of confidence, satisfaction and capture players' attention, remains questionable.

The overall finding on flow experiences was that Sg seems to have a slight advantage over and above MD with respect to the potential to sustain a player's attention – therefore partially complying with one out of possible nine dimensions of flow experiences. Regarding the basic requirements for effective learning environments, and motivational strategies, neither Sg nor MD could even partially comply with the set requirements.

6.4.2 Digital Game-based Learning (DGBL) games: Fish Shop (FS) and Grand Prix Pro (GPP) (Adventure games)

6.4.2.1 To what extent does FS and/or GPP represent design criteria of effective games?

In the discussion of these games, the reader is referred to the game descriptions of FS and GPP (Appendix E). As these games were developed by the same game developers, the only difference lies in the plot and storyline. Other design features (for example interface, controls, time and scorekeeping) are similar. These games will therefore be discussed in unison and individual differences (when applicable) will be outlined. Teachers' and learners' responses were analysed to determine whether FS and GPP display all of the design criteria central to the theoretical framework (Figure 6.3 and Table 6.2). The results are presented under individual game criteria.

- *Interactivity*

Interactivity is defined as iterative two-way actions (*interactivity*) between the player and the game context (*direct engagement)* in which both parties are allowed to make meaningful contributions towards the outcomes of the game (*control*) (Gunter et al., 2007). To be classified as *interactive*, games should create *a sense of direct engagement* and *control* in and over the game. Teachers responded by selecting eight positive responses to FS and selecting nine positive responses out of a possible 20 to GPP. With regard to *a sense of direct engagement* and *control* in and over the game, teachers found that none of these games make use of avatars to facilitate direct (yet anonymous) engagement in the game [QV[3]] (Pareto et al., 2012). These games did not provide adequate levels of control that could create a safe educational environment: players' "*actions can change outcome but only if they are able to provide correct answers"* [QY[3]]. Lengthy written pre-gaming explanations of game rules are supposed to promote interactivity by substituting the role of the avatar. Instead, the pre-gaming explanations were found to be counterproductive to promoting interactivity and was regarded as a "*waste of valuable gaming time*" [QV[2]].

Fish Shop (FS) and Grand Prix Pro (GPP) did, however, foster more control and direct engagement than CDP games as in both games answers were provided as multiple choice options. Teachers, however, stated that multiple option answering could also promote guessing and that it would be difficult to determine whether players provided correct answer due to luck or acquired skill [QX[4]]. Whitton (2010) argues that when a player's unique actions in a game do not lead to further changes in the game itself or generate individualised feedback from the game, it cannot be considered interactive. It can therefore be inferred that FS and GPP exhibit limited interactivity as feedback in terms of correct answer choices were provided. These games do not afford additional opportunities to rectify incorrect answers. When incorrect answers were provided, no corrective feedback were provided [QX[19]]. GPP was, however, found to be more interactive than FS because providing correct answers improved the racing speed. Ultimate control in and over the game however still relied on "*providing the correct answer*" [QY[3]] and incorrect answers resulted in a loss of control. None of the games facilitated independent navigation through the game as a rigid goal and rule structure presents [QY[4]]. Navigation came to a halt and time was forfeited when incorrect answers were provided. This aspect will be explored in more detail in the next paragraph.

- *Goal and rule structure*

FS and GPP were rated equal in terms of goal and rule structure and both received 15 positive responses out of 20. Goals and rules within the game, however, need to be aligned with the learning content and goal as well as the game goal (Denis & Jouvelot, 2005). Teacher Y commented on the rigidness of the rule structures of both games – reinforced by the fact that the game rules are in lengthy, on-screen reading format that prohibit players from commencing gameplay. *"FS and GPP provides written instructions upfront. Kids do not read long explanations. They want to start playing"* [QY[4]].

Despite the negative responses that could have derailed the start of the game, it can be inferred from the majority of positive responses that although rules were presented inappropriately and in a rigid manner before gameplay, it did not influence players' perceptions on how the game would play out. The final game and learning goal remained largely unpredicted and therefore the lengthy explanation of rules did not hinder gameflow by means of consuming too much cognitive resources of the player upfront (Song & Zhang, 2008). With less complicated games like FS and GPP game rules could however be inferred –reading of game rules were therefore redundant. Rigid and/or redundant game rules will therefore hinder gameflow and derail attainment of the learning goal (for example automatising of multiplication facts).

- *Situational interest*

Magner et al. (2012, p. 133) define situational interest as "a reaction to environmental input" and argue that all games need to elicit situational interest in order to be effective. It is, however, important in educational games as situational interest has the potential to evolve into individual learner interest. Once situational interest is triggered, individual interest will emerge as result of personal relevance or involvement (Plass et al., 2013). GPP and FS were evaluated in terms of whether situational interest was raised by *avoiding distractions* and thus ensuring continued *concentration.* Both games were rated nine out of a possible twenty positive responses and were therefore not compliant with *situational interes*t as criteria. It was found that 2D-graphics with limited change in scenery restricted situational interest. "*Experienced gamers will not be fascinated by 2D-graphics"* [QY[6]]. In-game *mystery* and *curiosity* are determining factors in raising situation interest (Song & Zhang, 2008). Both games were rated equally low in terms of mystery and curiosity "*FS and GPP does have written tuts at the reading level of the child, but it will not give them the feel of the game"* [QW[7]]. The background music in both games were also found to be disturbing and counter-productive to raising situational interested: "*irritating music"* [QV[6]].

- *Challenge*

Apart from the difficulty levels of the multiplication problems, the cognitive challenges within a game may easily exceed the learners' working memory capacity to process the auditory, textual or visual stimuli imbedded in the game design. As a result, cognitive overload occurs and impairs players' ability to process the essential information vital to fulfilling the game and learning goals (Mayer & Moreno, 2003). Teachers, however, responded that the simple, 2D-graphics did not cause extraneous distractions. "*In remaining games (FS; GPP) players will like the plot and I do not think 10-year-olds will be distracted or burdened by it."* [QW[13]]. *"Less experienced players will also be grabbed by FS and GPP"* [QY[10]]. From both games seven positive responses out of a possible 35 were obtained, it can therefore be inferred that neither FS nor GPP (despite the positive responses in previous paragraph), comply with the overall requirements of *challenge* as criteria for effective game design: Gee (2007) suggests the fact that learners can be successful at a stage (level) before the ultimate goals are reached as highly motivational. Gee (2007) refers to this motivational principle as: *performance before competence*. Respondents declared that players would probably not feel that they are able to *perform* in the game unless being declared *competent* at the end of a round due to guessing that could have happened (answers are provided in multiple choice format). "*To me, guessing does not count as cognitive load! (FS and GPP)-demotivating!"* [QW[11]]; "*FS and GPP can turn into guessing gam*es" [QV[12]].

- *Game context*

Devlin (2013) argues that an intriguing game context could intrinsically motivate players as players remain focussed on the game goal, plot and storyline and not the educational goal of the game. Respondents were, however, of the opinion that although the context of FS and GPP could intrigue less experienced players, the games were overall somewhat compliant with *game context* as game design criteria and received positive scores of 8 and 7 (respectively) out of a possible 15. Teachers Y, V and W declared that the *"countdown timer interferes"* [QY[14]] with enjoying the plot of the game in both instances …"*timer too prominent"* [QW[13]] and therefore a "*distracting factor*" [QX[13]]. Although there is some storyline – satisfying customers at the fish shop and winning a grand prix car race – *"experienced players will find them* (FS and GPP) *boring*" [QV[18]].

- *Feedback*

Feedback can be perceived as an umbrella construct that incorporates numerous other design details such as reflection, transfer and automaticity (Huang et al., 2013). On the issue of whether these games would foster reflection, transfer of knowledge and skills and ultimately automaticity, teacher respondents declared that feedback was provided but the effectiveness thereof only partially complied with the criteria; hence the positive response of 13 for FS and 14 for GPP out of a possible 25. Teacher respondents declared that feedback only consisted in terms of number of correct responses within a specific time frame [QX[19]]. In contrast to the CDP gaming environments, game rewards are extrinsic and can therefore be perceived as positive feedback: in FS the extrinsic game reward is the customer satisfaction (they leave the shop if dissatisfied) and in GPP the reward comes in the form of added power (speed) to your car. Neither can however be considered as effective, corrective feedback. The marginal difference of one response in favour of GPP could be attributed to the positive feedback of *added power* (GPP) being regarded as more extrinsic in nature then *customer satisfaction* (FS). It needs to be concluded that the type of feedback (although it might have fostered *reflection* and *transfer*) are not *corrective* feedback and are therefore not expected to foster *automaticity* as well.

- *Immersion*

Gunter et al. (2007) stress that although both interactivity and engagement are pre-requisites for immersion, engagement does not necessarily guarantee immersion, nor does interaction guarantee engagement. Therefore all the design criteria coordinating interaction and situational interest also come into play by contributing towards engagement experiences that can ultimately result in total immersion. In line with research findings of Cassell and Jenkins (1998), Roig and Hurtado (2004) and Hartmann and

Klimmt (2006) who commented on different genders having distinctive preferences regarding gaming content, boys and girls responded significantly differently on the capability of FS and GPP to immerse players. Boys and girls prefer games that represent the characters and roles traditionally attributed to their gender and reject those of the other (Roig & Hurtado, 2004). According to this statement boys would then favour GPP over and above FS as it is a racing car game – a game stereotyped as a boy game (Jenkins & Casell, 2008). From the boys' responses, a single positive response out of a possible 50 indicated that boys did not even indicate willingness to become engaged in FS. They were however more inclined to engage in GPP, but 12 positive responses out of a possible 50 are also indicative of not becoming fully immersed in the game either. In contrast to Roig and Hurtado's (2004) findings of girls being less prejudiced towards boys' games (GPP) than *vice versa,* the number of positive responses (4) in relation to the total number of responses (70) correlates with boys' reflection on girls' game (FS). The number of boys' responses indicating that GPP holds the potential for immersing them, were marginally lower than that of FS – indicating that girls felt more inclined to become immersed in the gender related FS game than boys in the gender- related GPP game. As the sample of game players for Phase 2 of the study consisted only of girls, the ultimate choice of game should take the results stated in this paragraph into consideration.

6.4.2.2 To what extent does FS and/or GPP demonstrate the criteria for effective CAI games?

To determine whether FS and GPP can be regarded as good educational (CAI) games, teachers' and learners' responses were also analysed to reveal these games' compliance with Song and Zhang's (2008) EFM model for effective educational games. The results will be presented under the three different aspects of the model (Effective learning environment, Flow dimensions and Motivational aspects).

- *Requirements for effective learning environments*

Are the basic requirements for effective learning environments represented in FS and GPP? To display the results and interpretations more effectively, a tabled format (Table 6.5) was used to pair the seven requirements of effective CAI learning environments (Song & Zhang, 2008) with relevant teacher responses and explanations obtained from the teacher questionnaire data.

Table 6.5. *Teachers' explanations (of their own positive or negative responses) organised according to criteria for creating an effective learning environment by means of FS and GPP as examples of 2D-adventure games.*

Song and Zhang's (2008) criteria for creating effective learning environments.	Relevant teacher explanations
Does the game provide a high intensity of interaction and feedback?	*"When learners are novice game players, FS and GPP may intrigue them."* [QX[8]] "Right or wrong only in game 1, 2, 3 and 4."[QW[18]].
Does the game set specific goals and established procedures?	"FS and GPP provides written instructions upfront. Kids do not read long explanations. They want to start playing." [QY[4]].
Does the game motivate learners towards attaining learning goal?	"FS and GPP does have written tuts at the reading level of the child, but it will not give them the feel of the game." [QX[8]] "FS and GPP: the guessing of correct answer can derail the learning goal of the game." [QV[18]] "Revealing the score prominently can be demotivating to struggling learners as they are confronted with the reality of the multiplication tables instead of pursuing the game goal." [QX[19]]
Does the game provide a continual feeling of challenge that is neither so difficult as to create a sense of hopelessness and frustration, nor so easy as to produce boredom?	"The 'guessing game' in FS and GPP (multiple choice answers) actually reduces the cognitive load. As player speeds through the game with no corrective feedback, it may seem as if he is competent enough to attempt more difficult questions." [QX[10]]. "To me, guessing does not count as cognitive load! FS and GPP-demotivating! Unjustified feelings competence." [QW[11]]
Does the game provide a sense of direct engagement?	"FS and GPP can turn into guessing game- demotivating." [QV[12]] *"Less experienced players will still be excited, FS and GPP,* but experienced players will find them boring." [QW[14]]
Does the game provide appropriate tools that fit the user and task so well that he can get aid and do not distract?	*"Less experienced players will also be grabbed by FS and GPP."* [QY[10]]. "FS and GPP less boring than first two due to some plotline, but countdown timer interferes." [QY[14]].
Does the game avoid distractions and disruptions that intervene and destroy the subjective experience?	*"In remaining games (FS; GPP) players will like the plot and I do not think ten year olds will be distracted or burdened by it"* [QW[13]]. "The prominent stop watch on the interface is extremely distracting." [QX[13]].

The first column (Table 6.5) displays the criteria for creating an effective learning environment in question format. The second column reveals the teachers' explanations of their own positive or negative responses to specific questions. Although teachers' responses and explanations thereof were on design criteria in general, the framework set in Table 6.2, directed the researcher to connect teachers' explanations to Song and Zhang's specific criteria for effective learning environments. In Table 6.5, the explanations of positive responses were indicated by means of italics. Although negative responses outweighed the positive ones, FS and GPP yielded more positive responses than the CDP games. Based on the teachers' responses and explanations, the following could be inferred: Neither FS nor GPP provided feedback in terms of the learning goal. Incorrect answers were accepted as wrong and no attempt was made to provide corrective feedback. These items were not necessarily repeated in subsequent rounds to provide players opportunities to correct. The only feedback provided, was in terms of the game goal (FS: number of satisfied customers and GPP: time in which race was completed). FS and GPP did set specific goals and established procedures but the way in which it were set out, however, remained questionable: rules need to be integrated into gameplay and not explained in written format before play could commence.

FS and GPP did not motivate learners towards attaining a learning goal as the score keeping within rounds of play was too prominent. The learning goal and game goal were not integrated and the progress towards the learning goal could only be obtained through providing correct answers by means of applied skill or fortunate guessing. As FS and GPP provided ample opportunities for obtaining correct answers by uninformed, random guessing or informed guessing (eliminating incorrect answers), unjustified feelings of 'performance before competence' (Gee, 2009) could have been created. On the other hand, if players would be able to provide answers without guessing, these games would not be challenging as the difficulty levels did not change between rounds.

Neither FS nor GPP could lead to feelings of direct engagement on the part of players. The possibility of novice players finding these games to provide direct engagement, however, existed. Both games displayed some indication of a plot and storyline (customer satisfaction - FS and winning a car race – GPP). The plot and storyline was, however, found to be shallow and only capable of intriguing novice players. In both games, the score and the time counter were prominently displayed on the game interface. Two teacher respondents found it disturbing and sometimes interrupting gameplay altogether.

- *Dimensions of Flow experiences*

Teachers' explanations of their own positive and negative responses were also analysed by means of Csikszentmihalyi's (1990) categorisation as exposed in sub-section 6.3, Figure 6.3 and Table 6.2 in particular.

- conditional factors

From analysis in the previous sub-section 6.4.2.1 as well as the current sub-section, FS and GPP were strongly condemned by teacher respondents due to the rigid rule and goal structure. Lengthy written descriptions of rules were provided upfront that set out the plot in detail instead of maintaining an element of mystery that would lure players to the game. Garris et al. (2002) and Shin et al. (2012) stress that although rules may be known beforehand, *how* the game plays out needs to remain unpredictable. If not, gameflow is interrupted. Although both FS and GPP provided feedback in terms of the game goal, no *unambiguous*, *corrective* feedback in terms of the learning goal could be found [QW[13]]. Without corrective feedback, players fail to be completely in control of the game. Without control, transfer of attained skills cannot be optimised as the player will not be motivated to repeatedly return to the game to practice skills (Paras & Bizzocchi, 2005). The multiple choice options regarding answers to multiplication tables as well as the difficulty levels not increasing between game rounds were found to be counter-productive to the challenge-skills balance within the game. As no feedback was provided in terms of correcting wrong answers and no higher levels of learning content was provided, the players could easily resort to guessing in order to advance in the game [QX[10]][QW[11]].

- experience factors

Teacher respondents commented that although novice players may experience a feeling of control over the game due to limited interactivity, experienced players will reject the game due to the fact that they will realise that their own actions cannot change the outcomes of the game as you are able to advance to a next round irrespective of number of correct answers provided [QX[8]][QY[10]][QW[13]]. In sub-section 6.4.2.1 it was stated that neither FS nor GPP were compliant with the design criteria of *situational interest.* As situational interest motivates the player to concentrate on the game goal (and indirectly on the learning goal as well), lack of attentional strategies can hinder gameflow (Ghani et al., 1991). The aforementioned lack of control over the game together with lack of these games' strategies to keep players' concentration at optimal levels resulted in separation between action and awareness. These factors were found to be inhibiting players reaching a state of deep and effortless involvement in the game.

- result factors

Learners' positive and negative responses on *immersion* provided data for determining whether FS and GPP would hold the potential to induce autotelic experiences (refer to Chapter 2 footnote 4), transformations of sense of time and loss of self-consciousness. Sub-section 6.4.2.1 revealed that boys and girls responded differently on the capability of FS and GPP to immerse players. The sub-section also concluded that although boys indicated possible immersion in GPP and girls indicated possible immersion in FS, none of these games truly holds the potential to immerse experienced players [QX[8]][QY[10]][QW[13]]. Therefore FS and GPP both fail to demonstrate result factors crucial to creating gameflow (Ermi & Mäyrä, 2005; Ijsselsteijn et al., 2007).

- *Strategies for stimulating Motivation*

Keller's ARCS model (1987) and Song and Zhang's EFM model (2008) propagate that eliciting, inspiring and maintaining motivation is the first step towards the design of environments that are conducive to learning. As requirements for motivation, these models prescribe *attention* (situational interest), *relevance strategies* (flexible goal and rule structure), *satisfaction strategies* (feedback) and *confidence strategies* (challenge-skills balance). All of these requirements were already discussed in the current and previous sub-sections. It would therefore suffice to say that FS and GPP seem to be unable to motivate experienced players to learn through gameplay due to the low quality attentional strategies (plot, sensory stimulation, curiosity, fantasy and/or mystery elements). Furthermore, the lack of challenge and in-game feedback hampered players' chances of feeling '*confident'* before actually being declared '*competent'* by the game (Gee, 2007; Shin et al., 2012; Whitton, 2010). Together with the rigid rule and goal structure that revealed the plot before gameplay could commence, the degree to which FS and GPP are able to create feelings of confidence, satisfaction and capture experienced players' attention, remains questionable.

To summarise the findings on FS and GPP it can be stated that although the learner respondents held distinctive gender preferences, neither FS nor GPP could comply with the criteria for effective CAI learning environments as laid down by the EFM model for educational game design (Song & Zhang, 2008). This summary is also reflected in the following teacher's comment: "*To me, guessing does not count as cognitive load! FS and GPP-demotivating! Unjustified feelings of competence"* [QW[11]].

6.4.3 Digital Game-based Learning (DGBL) games: Arithmemouse (Am) and Timez attack (TA) (3D-Adventure games)

6.4.3.1 To what extent does Am and/or TA represent design criteria of effective games?

When discussing Am and TA, the reader is, once again, referred to the in-game descriptions of these games (Appendix E) to be able to understand that although the same learning goal is pursued, the respective game goals are in stark contrast. Teachers' and learners' responses were evaluated to determine whether Am and/or TA did demonstrate the maximum number of game design criteria central to the theoretical framework (Figure 6.3 and Table 6.3). The findings are presented under the respective game design criteria.

- *Interactivity*

On the matter of whether the 3D-adventure games did foster direct engagement with and within the game, teachers provided the following feedback: both games were rated as fully compliant [QV[3]], [QX[4]], [QV[4]] and [QY[3]]. In both games the use of avatars that facilitate dialogue, searching and navigating as well as a feel of control over the game, were applauded. Faiola et al., (2013) assert that with the use of avatars interaction becomes even more anonymous, but simultaneously more freed, ensuring consequence-free environments that can be explored without any implications in the real world. Both games also fostered searching and navigation that determined the direction and flow of the game. "*Players' actions can change the outcome of the game"* [QY[3]]. In TA the avatar could be chosen according to a player's preferences. This aspect heightened control over the game (Whitton, 2010). *"Players' choices and responses* (via avatar) *will determine the outcomes of the game"* [QW[2]]. Players also felt that their play (not necessarily correct answers) could determine the outcome of the game. In TA, but not in Am, players are motivated to discover higher game levels [QX[2]]. Teachers also reflected positively on the initial guidance provided in both games that motivated players to control the game and the outcomes thereof. *"TA and Am provides built-in initial support"* [QY[1]].

- *Goal and rule structure*

Game rules and goals must be integrated with learning content into game design in such a way that it does not interrupt the flow of the game or negatively impacts on the entertainment value thereof (Denis & Jouvelot, 2005). Teachers commented that (although from different perspectives) both games present built-in intervention strategies: TA provided correct answers and drilling whereas Am focusses on incidental learning by means of modelling correct examples. TA was found to be fully compliant to this criteria whereas Am received 18 out of a possible 20 positive responses. The teacher explanations of TA's measures to evaluate attained learning goals could account for the difference in positive responses. TA provides 'checkpoints' (assessments) whereas Am deals with attaining of learning goals in a very informal manner (reinforcement by means of incidental learning, of which no proof is required). "*In TA there are levels and checkpoints that are reached timeously"* [QY[5]]. "*The content introduced after the checkpoints are more difficult*" [QW[4]]. Both games were commended for the smooth and flexible rule and goal structure that facilitated gameflow. Am's friendly mouse avatar lured players and explains rules was commended over and above the stern troll in TA that resorts to spanking as a method of reinforcement. "*Do like the way in which wrong strategy is addressed in Am. Does not like the spanking of the troll in*

TA." [QW5]. This endorsing of Am could however not fully compensate for the difference in assessment strategies as described in the previous paragraph. Overall, TA was thought to display a more conducive rule and goal structure.

- *Situational interest*

Magner et al. (2012, p.133) define situational interest as "a reaction to environmental input" and argue that all games need to elicit situational interest in order to be classified as effective learning games. Once situational interest is triggered, individual interest will emerge as a result of personal relevance or involvement (Plass et al., 2013). The characteristics of the interface design (sensory stimuli, curiosity, mystery and fantasy) are therefore crucial in eliciting individual interest by means of triggering situational interest.

All teachers (*n=5*) commented positively on the sensory stimuli, an atmosphere of curiosity as well as mystery and a fantasy world created within TA as well as Am. In TA, the situational interest, when compared to *all* other games, received the maximum number of possible positive responses (20) compared to 16 of Am. When analysing teachers' explanations though, it came about that they responded according to personal preferences and admitted to the fact that evaluation in this category was highly subjective. *"TA's music was irritating to me"* [QV8]. *"Sensory stimuli in last 2 games are worlds apart. It would depend on the personality of the child to state which is preferable over and above the other"* [QW6]. *"Love the soft, happy sound effects of Am"* [QX7]. *"Definitely! TA and Am: 'amazing' sensory stimulation"* [QY6]. The interface designs of these games were, however, perceived as significantly different in terms of sensory stimulation, curiosity, mystery and fantasy. Am was said to provide a "*playful bright environment"* [QV10]. "*Love the game atmospheres (although different) created by TA and Am. Am = calm and soothing; TA = mysterious and challenging"* [QY7]. "*TA's visuals are good, but the dungeon environment and ugly troll may be scary"* [QV9]. In both games the friendly avatars were viewed as the key element to creating situational interest. "*TA and Am have short intros where friendly avatars introduced players to the game without offending them (players)*" [QY8]. To single out a game would be (once again) a matter of personal preference.

- *Challenge*

Players need to be aware that the challenges of the game will be adjusted automatically according to their own ability at the point in time (Song & Zhang, 2008). The extent to which TA and Am are able to *create a continual feeling of challenge*, but simultaneously maintain a *challenge-skill balance* was to be determined. The positive responses revealed a 32 to 26 distribution (out of a possible 35) between TA and Am respectively. Teachers elaborated on sensible cognitive load and creating opportunities for players to feel that they can perform without declared competent yet. Although handled differently, both TA and Am ensured performance before competence (Gee, 2007): "*Feel good feelings up for grabs (TA and Am)"* [QX12] – teacher X commenting on the favourable balance between problem type and skill level of the player. Games "*respects diversity (challenges at own level) Am and TA."* [QV15]. *"In remaining games (TA and Am) players will like the plot and I do not think ten year olds will be distracted or burdened by it."* [QW13]. *"TA, because it is built upon error analysis- it takes on from the lowest level that the learner made mistakes on"* [QY12]. Although TA made use of mixed problem types, the game adjusted to the skill level of the player while simultaneously analysing errors so that multiplication skills could be reinforced by means of the troll repeatedly reinforcing multiplication skills – concentrating on previous errors. Am does not adjust the problem type according to skill level of the player, but the player can (initially) concentrate on the times tables that he/she is familiar with as problem types presented under the name of the specific times table for example "two times table (x2)"and players can therefore choose at which door (specific times table) to enter.

- *Game context*

This determines whether or not players could be intrinsically motivated to pursue the learning goal when game context enable them to remain focussed on the game goal, plot and storyline while (simultaneously) not over-emphasising the educational goal of memorising the bonds (Habgood & Ainsworth, 2005). Teachers found that both games displayed flexible, self-chosen plotlines. "*The entire story world of these games stand out from the rest*" [QX[14]]. *"Well-designed plot without doubt – TA and Am"* [QY[18]]. TA's plotline was believed to be more flexible, due to the fact that teachers were of the opinion that boys would not favour Am's plot *."Do not think boys will become emotionally attached to Am*" [QW[18]]. Teachers were also of the opinion that less experienced players would be drawn to Am with its simplistic game controls – arrow keys instead of computer mouse control. This could justify 14 as opposed to 15 (out of a possible 15) positive responses in favour of Am.

- *Feedback*

Optimal gaming feedback in educational games entails that the player should not only reflect on exposed learning content, but also engage with it appropriately so that transfer and eventually automaticity is reached (Gee, 2007; Shin et al., 2012; Whitton, 2010). Teacher responses and explanations thereof were studied for reflections on if, how and to what extent feedback is provided within the games. Teachers' explanations, however, revealed mixed responses, demonstrating that a choice between the two games would probably lie in personal interest in the game and not the game's power to facilitate automaticity: "*Love the fact that no scores are given in TA and Am"* [QW[20]]. *"Immediate feedback provided in both games, but the way in which it is conducted differ. Am definitely better, as it will lead to remembering the facts.* [QW[21]]. "Magical powers of troll in TA will make them remember their times tables better" [QV[24]]. *"TA provides delayed feedback; troll prompts and corrects before hitting avatar"* [QX[16]]. *"Am applied less drastic feedback measures* [QW[17]]. Both games were therefore rated favourably, but Am was found to be marginally more effective in terms of feedback – 21 as opposed to 20 responses out of a possible 25.

- *Immersion*

As the game samples were designed for children, the adult respondents (teachers), no matter how involved they could become with and in the game, could never have become totally immersed in the game. Only learners were therefore requested to reflect on the possibility of becoming immersed.

A significant discrepancy was found in the reflections of boys as opposed to girls. All of the girls indicated that they could become immersed in Am and some (29 out of possible 70) responses also indicated girls' potential immersion in TA. However, nine out the ten boys (45 responses out of a possible 50) indicated potential immersion in TA and a small number (10 responses) indicated potential immersion in Am as well. This is in line with Roig and Hurtado's (2004) finding that although players prefer gender specific games, girls are less prejudiced against boys' games than *vice versa*.

6.4.3.2 To what extent does Am and/or TA demonstrate the criteria for effective CAI games?

- *Requirements for effective learning environments*

To determine whether Am and TA demonstrate the requirements for effective learning environments, teachers' responses and explanations thereof were analysed. To display the results and interpretations more effectively, a tabled format (Table 6.6) was used to pair the seven requirements of effective CAI learning environments (Song & Zhang, 2008) with relevant teacher responses obtained from the teacher questionnaire data.

The first column (Table 6.6) reveals the criteria for creating an effective learning environment in question format. The second column reveals the teachers' explanations of their own responses relevant to a specific question. Although teachers' explanations were focussed on the design criteria in general, the framework set in Table 6.2, directed the researcher to connect teachers' explanations to Song and Zhang's specific questions on effective learning environments. The explanations of *positive* responses are indicated in italics in Table 6.6 to follow. In correspondence with the positive responses on the different design criteria of TA and Am in sub-section 6.4.3.1, teachers' explanations were overwhelmingly positive.

Table 6.6. *Teachers' comments (explanations of own positive and negative responses) organised according to criteria for creating an effective learning environment by means of Am and TA as examples of 3D-adventure games*.

Song and Zhang's (2008) criteria for creating effective learning environments.	**Relevant teacher explanations**
Does the game provide a high intensity of interaction and feedback?	"Both Am en TA prompt players by means of arrows if they are hesitant in manoeuvring the avatar through the maze [QV1] Dialoguing only found in Am and TA". [QX2] "Built-in support: Only in the case of TA and Ma [QY1] True control over the game only found in last two [QX3] Only Am and TA make use of avatars". [QV3] "In Am the player can choose if he/she wants to attempt 2x table instead of 9X – this could drastically change the outcome of the round". [QV4] (but not the entire game-added by researcher) "Players' choices and responses will determine the outcomes of the game."(Am/TA) [QW2] "Am and TA =actions can change outcome". [QW3] "Reflection in both games- effective: the best one? Will depend on personality of the player…some might not be impressed to be beaten over the head by an ugly troll".[QV21] "TA: effective delayed feedback. Troll provides a lot of chances to change answer before he strikes." [QX16]
Does the game set specific goals and established procedures?	"Am: the entire context of the game, led by the avatar actually explains the game rules." [QV6] "Like the inviting avatar that leads the way in Am" [QW4] "In TA there are levels and checkpoints that are reached timeously." [QY5]
Does the game motivate learners towards attaining learning goal?	"Own game strategies can be applied, but Am and TA provides motivating built-in support". [QV6] "Am and TA: many built-in support strategies should a player get lost". [QX6] "Well –designed plot without doubt.(Am/TA) Think boys will be more attracted to TA and girls to Am". [QY16] "Ugly troll derailing factor." [QW15] "Do not think boys will become emotionally attached to Am." [QW16]
Does the game provide a continual feeling of challenge that is neither so difficult as to create a sense of hopelessness and frustration, nor so easy as to produce boredom?	"TA does have checkpoints. The content introduced after the checkpoints are more difficult". [QW4] "In Am learners can choose the less challenging tables and in TA, after the diagnostic, the game plays out according to gaps in individual's knowledge and skills." [QW9] "Am: choose to proceed to more difficult level or not. TA: after checkpoints, more challenging levels. TA: teach skills before entering more challenging levels". [QV13] "TA error analysis". [QV14] "Am: teacher has to choose "doors" according to learners' ability at that point in time." [QW12] "Feel good feelings up for grabs." (TA and Am) [QX13] "Respects diversity (challenges at own level) Am and TA." [QV15] "TA because it is built upon error analysis- it takes on from the lowest level that the learner made mistakes on." [QY12]

Does the game provide a sense of direct engagement?	"Background music in Ta was irritating- could just as well be my sensitive ears and old age." [QV[8]] "Sensory stimuli very good". [QX[7]] "Sensory stimuli in last 2 games are worlds apart. It would depend on the personality of the child to state which is preferable over and above the other ".[QW[6]] " Love the happy, soft sound effects of Am". [QX[7]] "Definitely! TA and Am: amazing sensory stimulation." [QY[6]] "Visuals are fascinating- dungeons in TA could be a little scary though". [QV[9]] "Love the game atmospheres (although different) created by TA and Am. Am=calm and soothing; TA= mysterious and challenging." [QY[7]] "Experienced gamers will not be fascinated by first four; more by Am, but most in the case of TA (less predictable environment)." [QW[8]] "From the very first moment the avatars used in these games, will make the difference." [QX[9]]
Does the game provide appropriate tools that fit the user and task so well that he can get aid and do not distract?	"Do like the way in which wrong strategy is addressed in Am. Does not like the spanking of the troll in TA."[QW[5]] "TA provides a diagnostic test upfront which gives the player a glimpse of the plot and storyline." [QX[8]] "TA and Am has a short intro without challenges during which they are introduced to playing the game." [QY[8]] "Immediate feedback both games but the way in which it is conducted differ. Am definitely better, as it will lead to remembering the facts." [QW[21]]
Does the game avoid distractions and disruptions that intervene and destroy the subjective experience?	"Am will keep focus of players more than TA due to the playful atmosphere maintained."[QV[10]] "Am should also be using mixed examples- as in TA." [QV[20]] "Positive note on which feedback is given (TA) will leave no player unmotivated to proceed as he will not feel dumb or stupid." [QX[18]] "Love the fact that no scores are given in TA and Am." [QW[20]]

According to the teachers' explanations of their responses:

- Both Am and TA provides timeous corrective feedback on the attainment of the learning goal of the game (automaticity regarding times tables). The way in which feedback is provided, however, differs: Am provides ample time for reflection (delayed feedback) with the intention that the player should observe the correct answer that is prominently displayed while re-doing the round as to be able to provide the correct answer when provided a second (third or fourth) chance. This unintentional learning can be regarded as an *errorless learning approach[21].* TA also provides real-time feedback in the form of prompts at first and if unsuccessful, the correct answer is provided. The method is quite harsh as the seemingly unfriendly troll defeats (hit with a batten) the avatar. When answers are provided, the specific times table's facts are incorporated into the next level – retaught and re-assessed. To decide which of these two methods of feedback are preferable would not be possible as different players would prefer different methods – depending upon their unique character traits.
- The use of avatars introducing the game rules and goals are highly commended in both games. TA, however, stands out due to the fact that there are different difficulty levels with regular checkpoints to assess players' progress towards attaining the integrated learning and game goal. Am, on the other hand, has different rounds, but whether the rounds will be progressively difficult

[21] The term 'errorless learning' is used when mastering specific, low-level skills (like times tables) opposed to more complex skills. It may involve successfully completing target responses (correct answer) many times in order to increase proper encoding of the correct answer (Clare & Jones, 2008).

depends on the door (specific times table family for example x2, x3, x10) that the player chooses to enter. Both games were nevertheless commended for not displaying the score or time (TA: life) prominently; thereby not emphasising the learning goal over and above the game goal. Both games cater for individual differences: In Am the onus is on the player to choose difficulty levels that he/she is comfortable with. TA, however, has built-in strategies to keep the challenges at the skill-level or just above that of the player; thus adhering to Vygotsky's (1978) principle of keeping a learner in a Zone of Proximal Development (refer to Chapter 3, sub-section 3.2.2.2).

- Both games revealed an excellent (though very different) storyline and plot (refer to the game descriptions in Appendix E). The context of Am is placid and cheerful with a relaxed pace of play and soft, slow beat music while TA has a dark-coloured dungeon interface design with lots of mystery and a fast pace – spurred on by louder music with a fast and strong beat. To pinpoint the game that creates a more conducive CAI learning environment would, once again, depend upon the personal characteristics as well as the gaming and multiplication skill level of the learner. Higher skilled players with a positive self-image could be lured by the mysterious dark environment, while less confident players with a lower self-image might prefer that of Am as it could be seen as affectively more conducive.
- Teachers' responses clearly hinted towards distinct gender preferences and predicted that boys would be more drawn towards TA and will not emotionally attach to Am whereas girls would prefer Am. In sub-section 6.4.3.1) this prediction was verified. From learners' responses on possible immersion it came about that girls would, indeed, prefer Am and that boys were to be more intrigued by TA.
- Teachers commended the use of the initial diagnostic test of TA. This diagnostic test determines the skill level of the player in order to programme the difficulty levels of the multiplication facts to be introduced. It is, however, done in such a non-intrusive way that the player is of the opinion that the avatar only introduces himself /or herself to the game. Am, on the other hand, does not need to take the skill level into consideration as the problem types (multiplication table) is self-chosen by means of entering a door of choice at the beginning of each new round.

Dimensions of Flow experiences

Teachers' responses on Flow experiences will be revealed by means of Csikszentmihalyi's (1990) categorisation as revealed in sub-section 6.3, Figure 6.3 and Table 6.2 in particular.

- conditional factors

From the analysis in sub-section 6.4.3.1 as well as the current sub-section, TA and Am were both commended for smooth and flexible rule and goal structures that were exposed by the avatars while introducing players to the game in such a way that the storylines or plots were not completely revealed. Players were not exposed to lengthy descriptions and gameplay (or practicing gameplay) could start to no avail. This is in accordance with Garris et al. (2002) and Shin et al. (2012) who stress the fact that although rules may be known beforehand, *how* the game will play out needs to remain unpredictable. The goal and rule structure of TA and Am will therefore not interrupt gameflow. Both TA and Am provide ample feedback in terms of progress towards the game goal as well as the learning goal. The type of feedback can be regarded as timeous (real-time in TA and slightly delayed to support reflection in Am) as well as corrective. TA takes corrective feedback a step further than Am by providing opportunities for re-teaching and not just providing correct answers to observe and internalise as in the case of Am. By adjusting subsequent game levels to the skill level of the player after built-in error analysis during a previous round, TA is able to maintain optimal balance between players' skills and gameplay challenges. In contrast, the design features of Am did not allow for this type of skills-change balance as it relied on the player to match his/her skills to the different difficulty levels (challenge) that the game provides.

- experience factors

Situational interest motivates the player to concentrate on the game goal (and indirectly on the learning goal as well); hence strategies to keep players' concentration levels at optimal levels result in an action and awareness synergy that enhances gameflow (Ghani et al., 1991). The careful attention to the storyline, plot, sensory stimulation and elements of mystery, curiosity and fantasy resulted in situational interest to be raised in both games (despite the different contexts) resulted in the potential for players to reach a state of deep and effortless involvement in each game (Csikszentmihalyi, 1990).

- result factors

Learners' positive responses on immersion provided data for inferring that both TA and Am hold the potential to induce autotelic experiences (refer to Chapter 2, footnote 4), transformations of sense of time and loss of self-consciousness. Sub-section 6.4.3.1 revealed that boys and girls responded differently on the respective potential of TA and Am to immerse players. The sub-section concluded that boys were more inclined to become immersed in TA and girls in Am. Almost half of the girls, however, indicated that they would also become immersed in TA whereas only one boy indicated that he would also become immersed in Am. These findings are in accordance with Roig and Hurtado's (2004) finding that although players prefer gender specific games, girls are less prejudiced against boys' games than *vice versa*. Although marginal differences were found in the design features of Am and TA, both games display all of Csikszentmihalyi's (1990) aspects of flow that are also essential for creating gameflow (Ermi & Mäyrä, 2005; Ijsselsteijn et al., 2007).

- *Strategies for stimulating Motivation*

Keller's ARCS model (1987) and the model of Song and Zhang (2008) propagate that eliciting, inspiring and maintaining motivation is the first step towards the design of environments that are conducive to learning. As requirements for motivation, these models suggest *attention* (situational interest), *relevance strategies* (flexible goal and rule structure) *satisfaction strategies* (feedback) and *confidence strategies* (challenge – skills balance). The abovementioned requirements were discussed in detail in sub-section 6.4.3.2 and sub-section 6.4.3.1. It would therefore be adequate to state that both TA and Am harness the potential to motivate players to play as well as to learn due to optimally applying the following design features to serve the learning as well as the game goals: attentional strategies (storyline, plot, sensory stimulation, curiosity, fantasy and/or mystery), maintained balance between players' skills and gameplay challenges as well as flexible rule and goal structures. The distinct gender preference that was displayed and described in the previous two sub-sections revealed that girls would probably prefer

Am as an effective CAI learning environment and boys would probably prefer TA as an example of conducive educational game design (Song & Zhang, 2008). TA and Am display all the design criteria of well-designed educational games and can indeed be regarded as pedagogically sound learning environments promoting not only cognitive, but also affective learning behaviours (Felicia, 2012; Paras & Bizzocchi, 2005).

6.5 Synthesis of Chapter 6

The relevant research sub-questions that needed to be answered in this chapter were stated in the introductory section of this chapter (sub-section 6.1). As the answers to these questions could be obtained my means of the data analysis and results set out in this chapter and due to the fact that Phase 2 commenced by utilising the research instruments pointed out by answering to the research sub-questions, the chapter will henceforward attempt to answer to the first three research sub-questions:

Research sub-question 1: What is the conceptual value of adapting the SEMA instrument with regard to the research design of the study? Through adapting and re-adapting the SEMA instrument (Wu et al., 2012) after piloting the first draft, a final draft of the adapted SEMA instrument emerged (Chapter 4, Table 4.3). This instrument contains 11 statements that could be used in the group interview of Phase 2. The adapted instrument did not only contain statements, but also examples of open – ended prompts to potentially elicit deeper and more responses during the interview.

Research sub-question 2: What game design criteria would foster the automatisation of multiplication facts in CDP and DGBL computer-assisted instructional environments? Research sub-question 3: Which suitable computer games (for fostering automatisation of multiplication facts in CDP and DGBL environments) would optimally adhere to the game design criteria (identified by means of RSQ 2)?

Through the content analysis on computer game design criteria in Chapter 3, it was revealed that in order to foster automatisation of multiplication facts in both CDP and DGBL environments, a learning game needs to optimally display all of the researched design criteria (*game context, situational interest, rule and goal structure, challenge, interactivity, immersion and feedback*). Furthermore, irrespective of whether a game resorts under CDP or DGBL environment, it also needs to optimally comply with the design features of effective CAI learning environments as set out in Figure 6.3 and Table 6.2. Table 6.7 summarises the findings of the chapter (section 6.4) by means of reflecting on the established compliancy of all six games to the design features taken into account.

Table 6.7. CDP and DGBL games' compliancy with a) design criteria for effective games and b) design criteria for effective learning (CAI) games

		GAME DESIGN CRITERIA (data: teachers' and learners' responses)							CRITERIA FOR EFFECTIVE CAI LEARNING ENVIRONMENTS (data: teachers' responses)													
									REQUIREMENTS FOR EFFECTIVE LEARNING ENVIRONMENTS							DIMENSIONS OF FLOW EXPERIENCE			STRATEGIES FOR STIMULATING MOTIVATION			
		Game context	Situational interest	Rule and goal structure	Challenge	Interactivity	Immersion	Feedback	High intensity of interaction and feedback.	Specific goals and established procedures	Motivation towards attaining learning goal	Challenge- skills balance	Sense of direct engagement	Attentional strategies	Not derailing subjective experience	Conditional factors	Experience factors	Result factors	Attention strategies	Relevance strategies	Satisfaction strategies	Confidence strategies
CDP games	**SG**	X	X	X	X	X	X	✓	N	N	N	N	N	N	Y	N	N	N	S	N	N	N
	MD	X	X	X	X	X	X	X	N	N	N	N	N	N	N	N	N	N	N	N	N	N
DGBL games	**FS**	X	X	✓	X	X	X	✓	N	N	N	N	S	Y	Y	N	N	N	N	N	N	N
	GPP	X	X	✓	X	X	X	✓	N	N	N	N	S	Y	Y	N	N	N	N	N	N	N
	AM	✓✓	✓	✓	✓✓	✓✓	✓✓	✓✓	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	TA	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Key: Design criteria for effective games: **X** = not compliant (half or less than half of the responses were negative); ✓ somewhat compliant (more than half of responses were positive); ✓✓ compliant (more than 8 out of every ten responses were positive). **Design criteria for effective CAI games**: Y = fully compliant; S= somewhat compliant; N= not compliant

Table 6.7 displays the compliancy of the different CDP games in row 1 and 2 as well as the compliancy of DGBL games in rows 3 to 6 to the criteria for effective game design and the criteria for effective learning game (CAI) design. The latter set of design criteria was to be sub-divided into requirements for effective learning environments, dimensions of flow experience and strategies for simulating motivation as displayed in the conceptual framework (Figure 6.3 and Table 6.2) and discussed in sub-section 6.3 of this chapter. The reader is requested to take cognisance of the fact that although tabled as separate, all of the design criteria are linked and overlapping (as pointed out in the chapter section: conceptual framework – sub-section 6.3). As the data have been analysed in different chapter sub-sections, the summative analysis results are also tabled in different columns.

According to the research design set out in Chapter 4 one CDP game and one DGBL game that could be used as research tools in collecting data by means of gameplay were required. Design criteria to optimise learning goals are universal and span across all genres of gameplay. In terms of the current investigation, CDP games and DGBL games should therefore comply optimally with all of the identified criteria for effective games as well as effective learning games. Due to the nature of CDP games (refer to literature review in Chapter 2) and according to the findings revealed in sub-section 6.4.1.1, CDP games did not comply with the design features of effective gaming at all.

When referring to Mathematics education, Hardman (2005) argues that although a general presumption prevails that the CAI in schools would positively impact on learners' performance and motivation and heighten interest in the subject, the choice of software programmes is one of the crucial factors in attaining this goal. Hardman (2005) also stresses the fact that it is common practice to only use CAI in South African schools for drill and practice of low levelled skills (automatisation of multiplication facts for example) instead of also using it as a learning tool to obtain or reinforce higher order thinking and reasoning skills. The choice of a CDP game for Phase 2 of the research project, is therefore valid as well as significant as affective responses to the various design criteria (or lack thereof) were observed in order to answer to the main research question (describing learners' *anxiety* – affective responses – while automating multiplication facts in CAI environments). Representing CDP games, Smartygames (Sg) will be used during gameplay sessions as it complied more favourably with the investigated design criteria than Multiplication Drill (MD). Through analysis of teachers' and learners' responses as well as teachers' explanations thereof, it could be inferred that although both games were equally non-compliant, Sg's feedback in terms of the game and learning goal marginally surpassed that of MD.

As revealed in sub-section 6.4.2.1, Fish Shop (FS) and Grand Prix Pro (GPP) did not fully comply with most game design criteria. It could also be stated that these two games would not interest experienced game players. The lower level of compliance with game design criteria as well as the high level of prior gameplay experience of the purposive selected sample of game players, the choice of a game in the DGBL domain was to be decided between Arithmemouse (Am) and Timez Attack (TA).

By reviewing Table 6.7 it became clear that both Am and TA complied with the game design criteria as well as the game design criteria for *learning games* in an excellent manner. As revealed in sub-section 6.4.3 distinct differences were nevertheless recorded in terms of a) dialoguing and methods of searching and navigating through the games, b) the way in which games create mystery to raise curiosity, c) the type and nature of the sensory stimulation, d) how *performance before competence* is created, e) how automaticity is pursued, f) the type of storyline and g) the game's capacity to harness complete immersion.

When evaluating TA and Am on the compatibility to Song and Zhang's (2008) EFM-model for education game design, TA marginally surpassed Am in terms of meeting the requirements of effective learning environments. In contrast to this phenomenon, Am displayed a slightly higher potential to induce flow experience, as girls displayed a better inclination to become immersed in this game. A boy indicated that he would become immersed in Am, but not in TA. Seven girls though, indicated that they would also become immersed in TA; not only in Am.

A logic and natural outcome of this identification process was to abandon the use of *only one* game in each of the CAI domains, and add another gameplay session to incorporate both DBDL games in question. As the respondents consisted only of girls and not boys, it was anticipated that valuable data could be obtained by observing girl respondents' flow experiences in both contrasting game contexts. The gameplay sessions in Phase 2 of the study therefore incorporated Smartygames as an example of CDP game and *both* Arithmemouse and Timez Attack as examples of games in the DGBL domain.

Chapter 7 will reveal the findings of the second research phase (Phases 2A and 2B).

Chapter 7

Presentation of the findings: second data analysis phase

"Ma'am, me and Math…we keep our distances!"
(Research participant, 2014)

7.1 Introduction

Data were collected in two phases that culminated into two distinctively different phases of data analysis. The findings of the first phase were presented in Chapter 6. Chapter 7 presents the findings of the second analysis phase. Although overlapping and pertaining to the main research question "To what extent do Grade 4 learners experience anxiety in computer-assisted instructional environments during automatisation of multiplication facts?" this analysis phase focused on the fourth, fifth and last (sixth) research sub-questions as set out in Table 7.1. A schematic representation of the sequential steps followed during Phase 2 were set out in Chapter 5, Figure 5.1.

Table 7.1 indicates the research sub-questions that inform the investigations that took place during Phase 2. The table also contains the corresponding chapter sections in which the results and findings are revealed. The chapter will then continue by discussing the theoretical and the different conceptual frameworks utilised during the analysis of the collected data. Thereafter the analysis findings will be presented.

Table 7.1. Research sub-questions informing Phase 1 investigations and the corresponding chapter sections revealing the results and findings thereof

Research sub-question number	Content: research sub-questions	Relevant chapter sections
4	*To what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home teaching environments during the automatisation of multiplication facts?*	7.3.1
5	*To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?*	7.3.2
6	*To what extent, if any, do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?*	7.3.3

7.2 Conceptual Frameworks

Due to different perspectives from which *anxiety↔ confidence* valence is investigated, different sections of the overall framework outlined in Chapter 2 (sub-section 2.3) were utilized to analyse different types of verbal and non-verbal data collected. Figure 7.1 replicates the overall theoretical framework of the study as set out in Chapter 2 (Figure 2.2), but simultaneously emphasises the specific theoretical frameworks against which the data collected in Phase 2 were analysed.

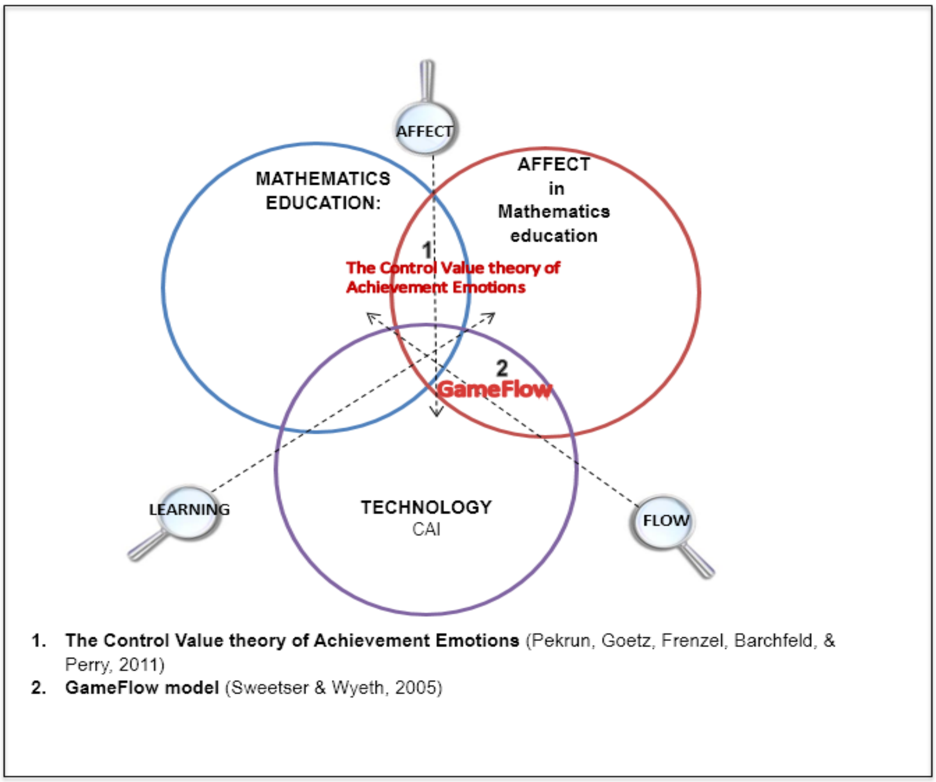


Figure 7.1. Conceptual framework against which analysis of Phase 2 took place - indicating the focal areas (1 & 2)

The specific theoretical framework (Control Value Theory of Achievement Emotions and/or GameFlow model) and supportive conceptual frameworks used in analysing the different data sets will be explained in detail in the next two sub-sections (7.2.1 and 7.2.2)

7.2.1 Verbal data

With regard to both the group interview as well as the individual interviews post gameplay sessions, Pekrun et al.'s (2011) Control Value Theory of Achievement Emotions – as described in Chapter 2, sub-section 2.3.4.1– led to conceptual frameworks (Figures 2.6 and 2.7) that were applied to understand the verbal accounts of anxiety experiences during conventional teaching and computer-assisted instruction. The observations enabled understanding the participants' beliefs and attitudes that could possibly have influenced their anxiety experiences related to automatisation of multiplication facts.

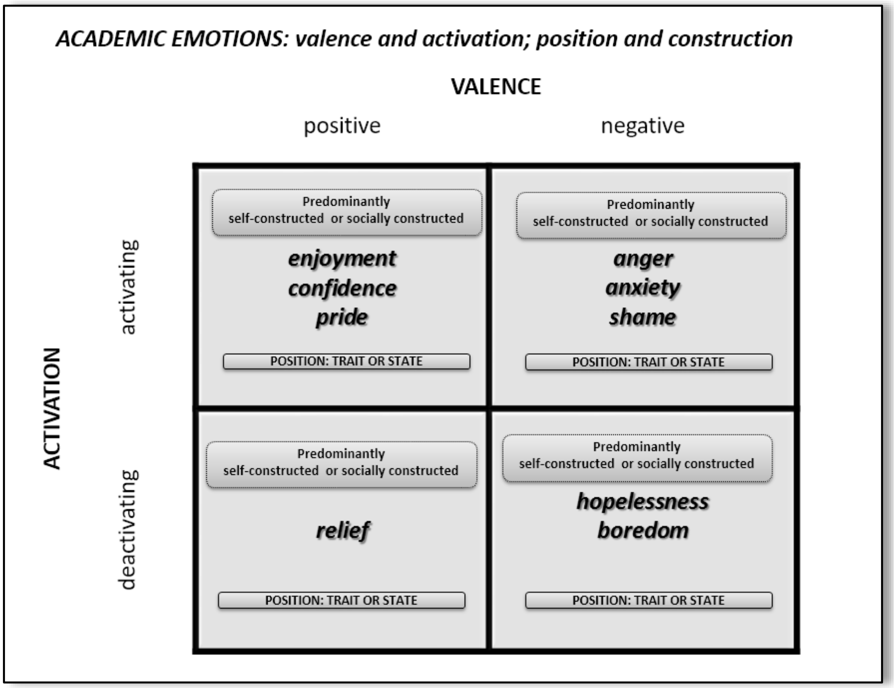


Figure 7.2a. Academic emotions: depicting valence and activation; position and construction

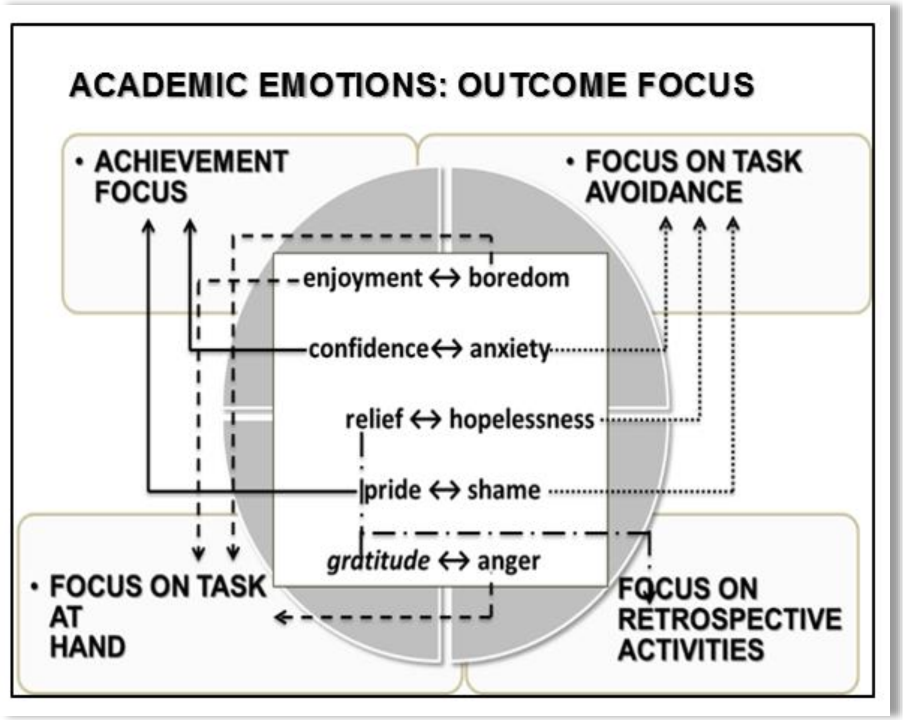


Figure 7.2b. Academic emotions: depicting valence and activation and outcome focus

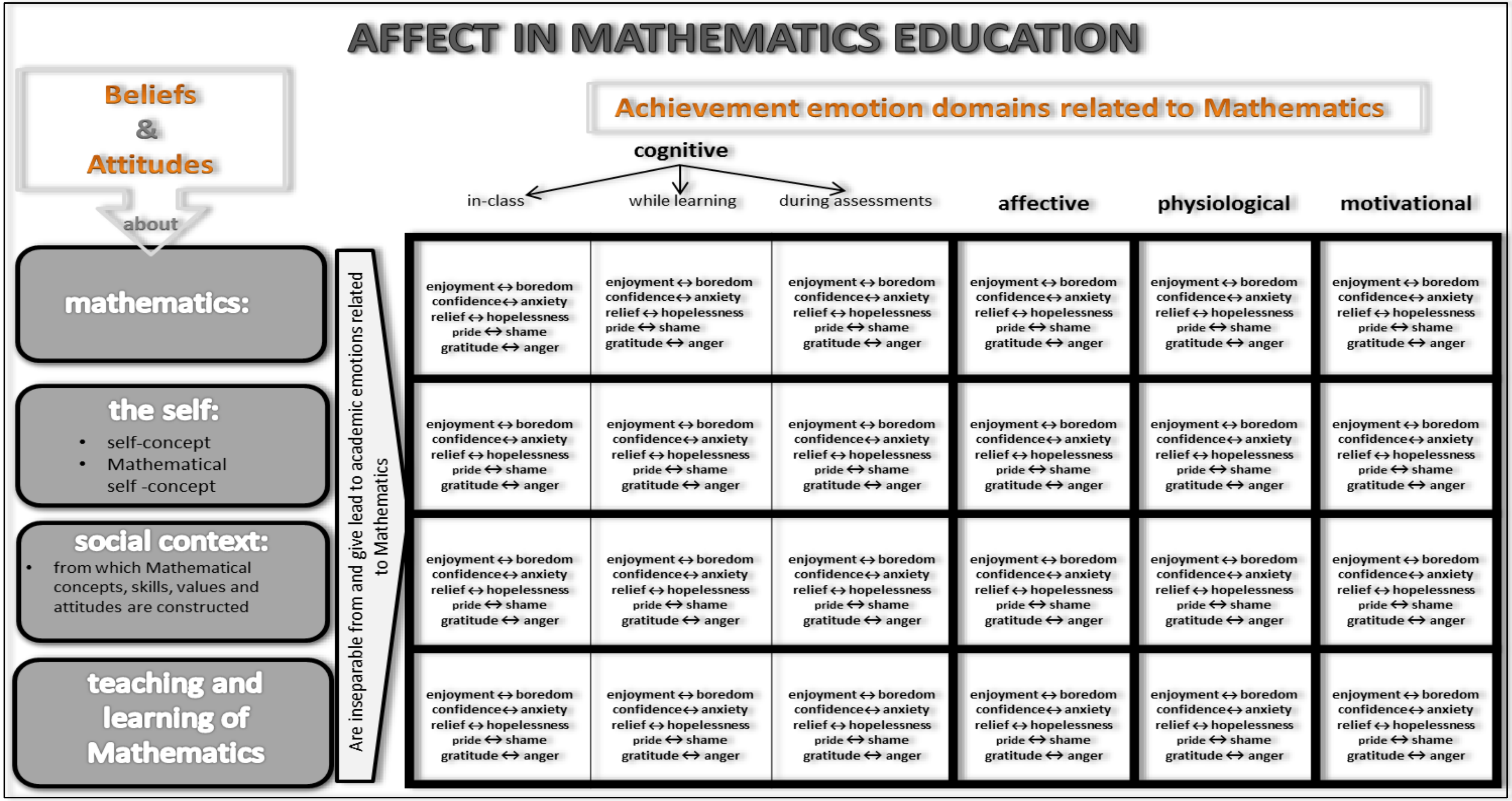


Figure 7.3. Affect in Mathematics education: depicting belief and attitude domains as well as academic emotion domains

With regard to the data collected during the post-gameplay interview sessions, an additional model, Sweetser and Wyeth's (2005) GameFlow model, was used as conceptual framework for analysing the differences (if any) in enjoyment experiences while playing in CPD environments opposed to DGBL environments. The reader is referred back to Chapter 2, sub-section 2.2.5 for a discussion of the model. Table 7.2 below, however, contains a summary of the model.

Table 7.2. *GameFlow Model for Enjoyment (Sweetser & Wyeth, 2005)*

GameFlow components	
CONCENTRATION	**CONTROL**
Games must keep the player's concentration through a high work-load.	If players are sufficiently skilled, the tasks have clear goals and the game provides feedback, then players will feel a sense of control over the task.
CHALLENGE & PLAYER SKILLS	**IMMERSION**
Tasks must be sufficiently challenging to be enjoyable The player must be skilled enough to undertake the challenging tasks.	Abovementioned elements culminate in total immersion or absorption in the game: players lose awareness of everyday life, lose concern about the self, and their sense of time may be altered.
CLEAR GOALS AND FEEDBACK	**SOCIAL INTERACTI**ON
Tasks must have clear goals so that the player can complete the tasks, and the player must receive feedback on progress towards completing the tasks.	"People play games to interact with other people, regardless of the task, and will even play games they do not like or even when they don't like games at all" (Sweetser & Wyeth, 2005, p.4)

7.2.2 Non-verbal data

Non-verbal data was obtained from the video recordings of the gameplay sessions. The conceptual framework (Appendix A) informed the analysis of the non-verbal data collected. This conceptual framework originated from research findings revealed by means of literature studies as described in Chapter 2, sub-section 2.4.2. It contains a list of the facial expressions, gestures, body movements, postures and vocal interjections associated with academic emotions (confidence, anxiety, enjoyment, boredom, relief, hopelessness, pride, shame and anger).

Both verbal and non-verbal data accumulated in the second phase of the research were analysed to answer to last two research sub-questions (RSQ 5 and RSQ 6) (see Table 7.1)

7.3 Findings: Second Data Analysis Phase

As the researcher constantly moved back and forth between different types of verbal and non-verbal data while analysing, the order in which the findings and interpretations are presented do not necessarily follow the order in which data was collected. Figure 7.4 guides the reader in following the way in which the findings of this phase will be presented.

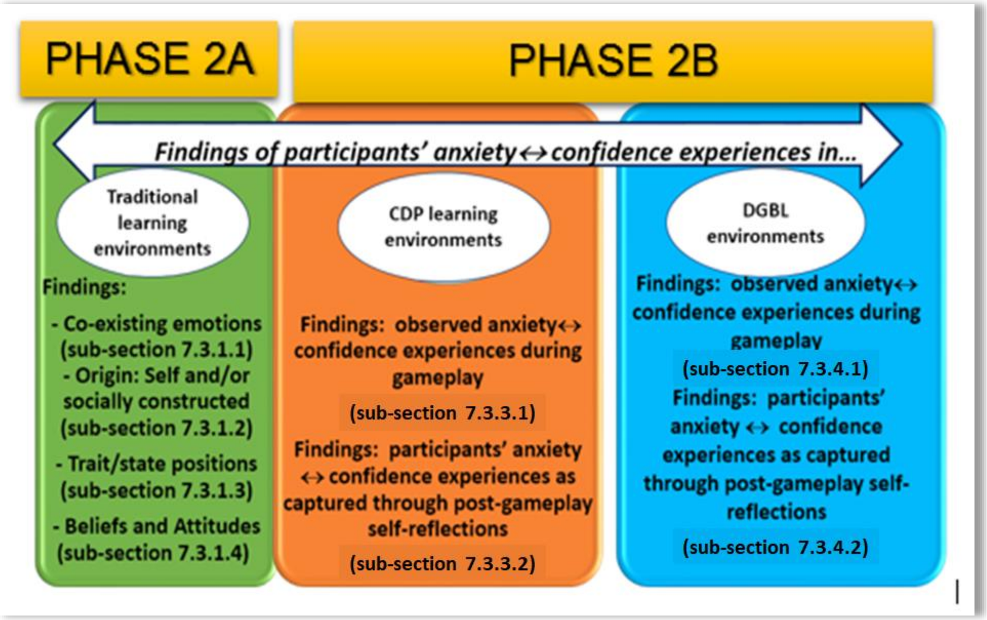


Figure 7.4. Graphic representation of presentation of findings

Data collected during the focus group interview (using the adapted SEMA questions to elicit reflections on participants' *anxiety↔confidence* experiences) led to some significant findings on co-existing emotions, on the origin and position of emotions experienced and the beliefs and attitudes about Mathematics as experienced in the traditional learning environments of both classroom and home. (Phase 2A). These findings will be revealed first and will be followed by findings on participants' *anxiety↔confidence* experiences during Phase 2B: *Anxiety↔ confidence* experiences in CDP learning environments (reflected through gameplay and post-gameplay individual interviews) and *anxiety↔confidence* experiences in DGBL environments (reflected through gameplay and post-gameplay individual interviews) will be revealed.

7.3.1 Findings Phase 2A: participants' anxiety↔confidence experiences during automatisation of multiplication facts in conventional learning environments

The re-adapted SEMA instrument questions and statements were not only used to elicit responses in terms of 'degree of nervousness', but also to probe participants' explanations for their own responses. The transcription of the interview was read and re-read to identify constructs as described in sub-section 7.2.1. Atlas.ti software was used to code, quote and connect research notes (memo's) to quotations.

Thereafter, different network views (Figure 7.6a and Figure 7.6b) were compiled to reveal results that enabled findings on the data. Network views were organised from the following perspectives: labelling of the academic emotions revealed during group interview, classification of academic emotions in terms of self-construction or social construction with emphasis on anxiety and confidence, identification of trait and state positions as well as outcome focus of experienced academic emotions and beliefs and attitudes with regard to mathematics, mathematics self-concept, the social context of attaining computational fluency and the teaching and learning of multiplication skills.

7.3.1.1 Co-existing emotions

Although the SEMA instrument was originally designed to obtain statistical evidence of the prevalence of Mathematics anxiety, Pekrun et al. (2011) advise researchers to view and investigate anxiety in terms of and in relation to all other academic emotions. Villavicencio and Bernardo (2013; 2015) also urge researchers investigating Mathematics anxiety, to not only investigate co-existing negative emotions, but especially probe into co-existing positive academic emotions. When the density of the codes was observed, substantial feelings of *anxiety* (37 manifestations) but also a significant 31 manifestations of *confidence* were recorded (Figure 7.7a & Figure 7.7b). The high prevalence of *confidence* however needs to be viewed against a background of 'seemingly confident' or 'false confidence' of which evidence could be obtained. This aspect will be explained in sub-section 7.3.1.4. Limited feelings of *anger* were expressed and were only mentioned in discussions of parental support in terms of drilling times table facts *[QU 1:27] [par.37].*

The analysis of the interview data did not yield any manifestation of *enjoyment. Relief* and *pride* were indicated in a few statements though *[QU 1:9] [par.12]* and *[QU 1:10] [par.19]* where two participants did not regard working with 'time' and 'money' as engaging in Mathematics. *Shame* and *hopelessness* were indicated often and coincided with anxiety as if following one another in a 'degrees of comparison' statement: 'anxiety….hopelessness….shame'. For example: *"When I get stuck I just sometimes want to scream and say help me and then I go like what is wrong with my head?" "I see that you then start to panic." "Yes ma'am." [QU 1:46] [par.68].* The observed feelings of anxiety soon spilled over into *hopelessness [QU 1:45]* and eventually into *shame [QU 1:44] [par.66]* as outlined in the next paragraph. To enhance understanding of the co-existing emotions' manifestations, the reader is referred to Table 7.5 and Appendix G as well.

"Ma'am sometimes I want to jump off my chair and say: What is the number (answer)?" "And then you get cross with yourself for not remembering?" "Yes ma'am." "Who gets a good-for-nothing feeling when not being able to remember? (Participants all raise hands) Yes all of you." [QU 1:45] [par.67] "No, she (teacher) will definitely get cross because I am supposed to know my things like times tables and stuff like that. If you ask anybody ma'am… she will always say times tables this Friday, study them. So if you don't know your times tables ma'am then it is obvious that you don't study them." [QU 1:44] [par.66].

7.3.1.2 Classification in terms of self-constructed or socially-constructed academic emotions with emphasis on anxiety↔ confidence valence

Analysis of the group interview data revealed findings as exposed in the network view in Appendix G. This appendix illustrates two of these academic emotions (*anxiety* and *confidence*) in relation to the respective positions in terms of *construction*. (see Chapter 5, sub-section 5.4.2.1 for coding procedures). As example, a code labelled X15 ANX B 4 ** can be explained as follows: X15 refers to the affective domain in which beliefs and attitudes (about mathematics as a social activity) is formed. ANX refers to the observable academic emotion: anxiety whereas B indicates that in the specific context, anxiety was observed as predominantly socially constructed (opposed to A that would have indicated predominant self-construction). Furthermore 4 indicates that the participant focussed on self-reflective activities (opposed to focussing on achievement outcomes, the task at hand or on task avoidance). ** refers to a 'state' (opposed to 'trait' position) and implies that anxiety as observed academic emotion is sporadically experienced – and only experienced in and associated with a specific context.

Confidence was found to be mainly self-constructed. Participants' *confidence* in their own ability (math self-concept) [QU 1:12] [par.19], *confidence* regarding the social context in which learning takes place [QU 1:10] [par.19 as well as *confidence* in the process of teaching and learning mathematics [QU 1:37] [par.54] were interpreted as self-constructed as it could not be identified that it originated due to extrinsic triggers.

Anxiety, on the other hand, was found to be expressed as a mixture of self- and socially constructed origins. Learning and being assessed as members of a social group were outlined as major triggers of socially-constructed feelings of anxiety.

As explained in the previous sub-section (7.3.1.1), a sequential order of manifestations of anxiety, *hopelessness* and *shame* seemed to exist. Figure 7.5 illustrates this phenomenon by extracting and reorganising nodes from Appendix G.

Figure 7.5. Sequential prevalence of anxiety, hopelessness and shame within same context

This observed phenomenon explains how contexts in which socially constructed *anxiety* were experienced could spill over into consecutive feelings of *hopelessness* and *shame* within the same context. The following three contexts pertains - X14 (Beliefs about the self in the affective domain of academic emotions), X15 (Beliefs about the social context in the affective domain) and X22 (beliefs about the self in the motivational domain). When the density and groundedness of the node (depicting the intensity) however increased in the context (X11- beliefs about the self in the context of Mathematics assessment), *anxiety*, turned into shame without displaying feelings of hopelessness in between. This observed phenomenon could also point to the difference between positive stress - *healthy anxiety*, also referred to as *excitability* by Hackbarth et al*.* (2003) and negative stress (anxiety). Whereas positive stress is said to occur in close contingence with a stressor, negative stress (anxiety) may also occur in the absence of the stressor. When aforementioned stressor distinction is taken into consideration, it could be concluded that anxiety (and not positive stress) could result in a downward spiral of cascading into other negative academic emotions of *hopelessness* and *shame*. An example of this observed downward spiral:

ANXIETY: "When I get stuck I just sometimes want to scream and say help me and then I go like what is wrong with my head?" "I see that you then start to panic." "Yes ma'am." [QU 1:46][par.70].

*HOPELESSNESS: "Ma'am sometimes I want to jump off my chair and say: What is the number (*answer*)?" "And then you get cross with yourself for not remembering?" "Yes ma'am." "Who gets a good-for-nothing feeling when not being able to remember?* (Participants all raise hands) *Yes all of you." [QU 1:45][par. 71].*

SHAME: "No, she (teacher) *will definitely get cross because I am supposed to know my things like times tables and stuff like that. If you ask anybody ma'am… she will always say times tables this Friday, study them. So if you don't know your times tables ma'am then it is obvious that you don't study them." [QU 1:44[par.71].]*

The X15 context furthermore displays that the feelings of *shame*, although originated socially, can be experienced 'wrongfully' as self-constructed. The following quotation, [*QU 1:30] [par.40],* provides the scenario for X15 above: The teacher demanded from the learner to provide answers in front of class, without her being confident yet; hence expecting *confidenc*e before *competence*. As learner failed to provide correct answers, she was left with feelings of *hopelessness* when a so-called 'brighter learner' provided answer and when situation repeated itself, learner was left with feelings of *shame*. *"Ma'am, I did know the answer to the sum and then the next thing I forget it and then the class laughs at me. But then the ma'am told XXXXX to please give the class the correct answer"…. After what happened at school I started hating it." [QU 1:30] [par.40].*

In all recorded incidents, the construction origin of the remaining co-existing academic emotion of *anger,* was found to be extrinsic whereas the remaining co-existing emotion, *pride,* had always been constructed intrinsically. The manifestations of boredom and relief although limited, could also be observed. The next sub-section aims to provide clarity on the different positions and outcome focus of *anxiety↔confidence*.

7.3.1.3 Identification of anxiety↔confidence trait and state positions as well as anxiety↔confidence outcome focus

By plotting the codes about *position* on a matrix, the domains (origin) of *anxiet*y and *confidence* emotions could be represented. Figure 7.6 displays this matrix. The matrix uses the conceptual framework (Figure 7.3) to plot the relevant domain in which the academic emotions of *anxiety* and *confidence* were observed.

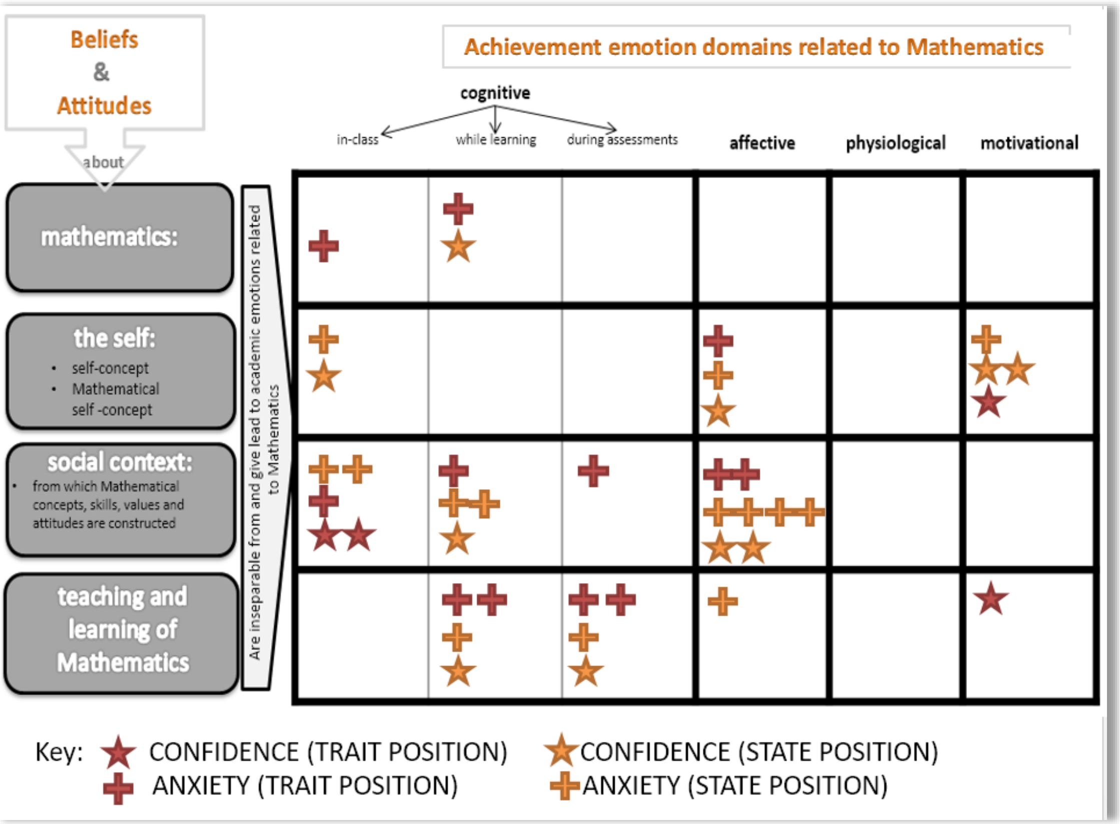


Figure 7.6. Confidence↔ anxiety valence in terms of trait or state position

The reader is referred to Appendix G to familiarise him/herself with the data used to compile the matrix (state or trait position indicated by * and ** with respect to both anxiety and confidence experiences). The researcher's anecdotal field notes on the personal observations during the interview were combined with data from the verbatim transcriptions of the focus group interview. Refer to Appendix G that displays the integrated data as analysed. The analysed data revealed 37 manifestations of *anxiet*y and the 31 of *confidence.* Valid findings on the *position* of these academic emotions should however not only be derived from once-off interview findings. This aspect should be viewed as a limitation to the research. The findings therefore need to be viewed as preliminary. In terms of position, *anxiety* were found more in state position (14 manifestations) than trait position (12 manifestations). *Confidence*, in a trait position (four manifestations) were, however, three times lower than that of anxiety (12 manifestations). The state positions of *confidence* (10 manifestations) were significantly higher than that of *confidence* in trait position (four manifestations). Manifestations of *anxiety* in state and trait positions, however, almost correlated in terms of number (14 vs.12). State positions of short-lived *anxiety* states that are consciously and subjectively perceived often 'stick' and without being relieved or resolved could become a chronic situation (trait position) (Belbase, 2011; Pekrun et al., 2002; 2011). Brief experiences of *confidence* as described by three participants (10 manifestations) could therefore turn into more permanent feelings of confidence, but the comparable number of *anxiety* experiences in state position (14 manifestations) could also turn into more permanent feelings of *anxiety* should it not be resolved or relieved.

Anxiety and/or *confidence*, in trait position, imply that the emotion can be experienced in any situation associated with the specific fear or confidence without the person being in the context or situation(s) where the emotion(s) had been experienced in state positions previously (Belbase, 2011; Pekrun et al., 2002; 2011). Participants pointed to three times more anxiety experiences (12 manifestations) than confidence experiences (four manifestations) in this position.

In terms of the tallied 37 manifestations of *anxiety* and the 31 of *confidence* referred to during the interview, the *outcome focus* could be tallied as illustrated in Table 7.3 below.

Table 7.3. *Outcome focus: anxiety and confidence*

	OUTCOME FOCUS			
	Focussed on achievement	**Only focussed on task at hand**	**Focussed on task avoidance**	**Focussed on retrospective activities**
Number of *anxiety* manifestations	10	17	3	7
Number of *confidence* manifestations	31	0	0	0

The results in this table (Table 7.3) supports Pekrun's (1992) finding that *anxiety* experiences distort learners' outcome focus. Although the topic of discussion during the group interview was automatisation of multiplication facts and it was only discussed in a single group interview situation, the majority of manifestations of anxiety pointed to focus *on the task at hand* and not on *achievement outcomes*. Learners were clearly not able to focus holistically and set mastery goals for themselves. Although there were some focus on achievement outcomes, learners seemed to be in a state of "*learning for nothing*". These findings will be explored further in Chapter 8, sub-section (8.4.1.1) when reflected upon in relation to other findings.

7.3.1.4 Beliefs and Attitudes with regard to a) mathematics, b) mathematics self-concept, c) the social context of attaining computational fluency as well as d)the teaching and learning of multiplication skills

Beliefs and attitudes were analysed by not only making use of codes and quotations, but also memos that incorporated researcher's field notes. In this way, a network view could be constructed for negative beliefs and attitudes (emphasising observed *anxiety*) and a separate network view for positive beliefs and attitudes emphasising observed *confidence*). By viewing and organising data as displayed in Figures 7.7a and 7.7b, specific themes emerged from the annotations of the transcription and from the observational field notes of the researcher (see, for example, memo 1:27, 1:30, 1:35). The findings will be stated under *negative attributions* followed by *positive attributions*.

- *Negative attributions*

All six participants attended an induction session beforehand where they were (by following Sisemore, 2008), guided through a process during which they could link the items on Sizemore's (2008) nervous thermometer (degrees of worry) to the degrees of nervousness as stated on the artefact they used to assist verbal responses to the interview statements. Despite demonstrating their understanding of degrees of nervousness and worry, it could still not be taken for granted that during the interview participants' understanding of *anxiety* would be accurate enough to lead to valid interpretations during the analysis process.

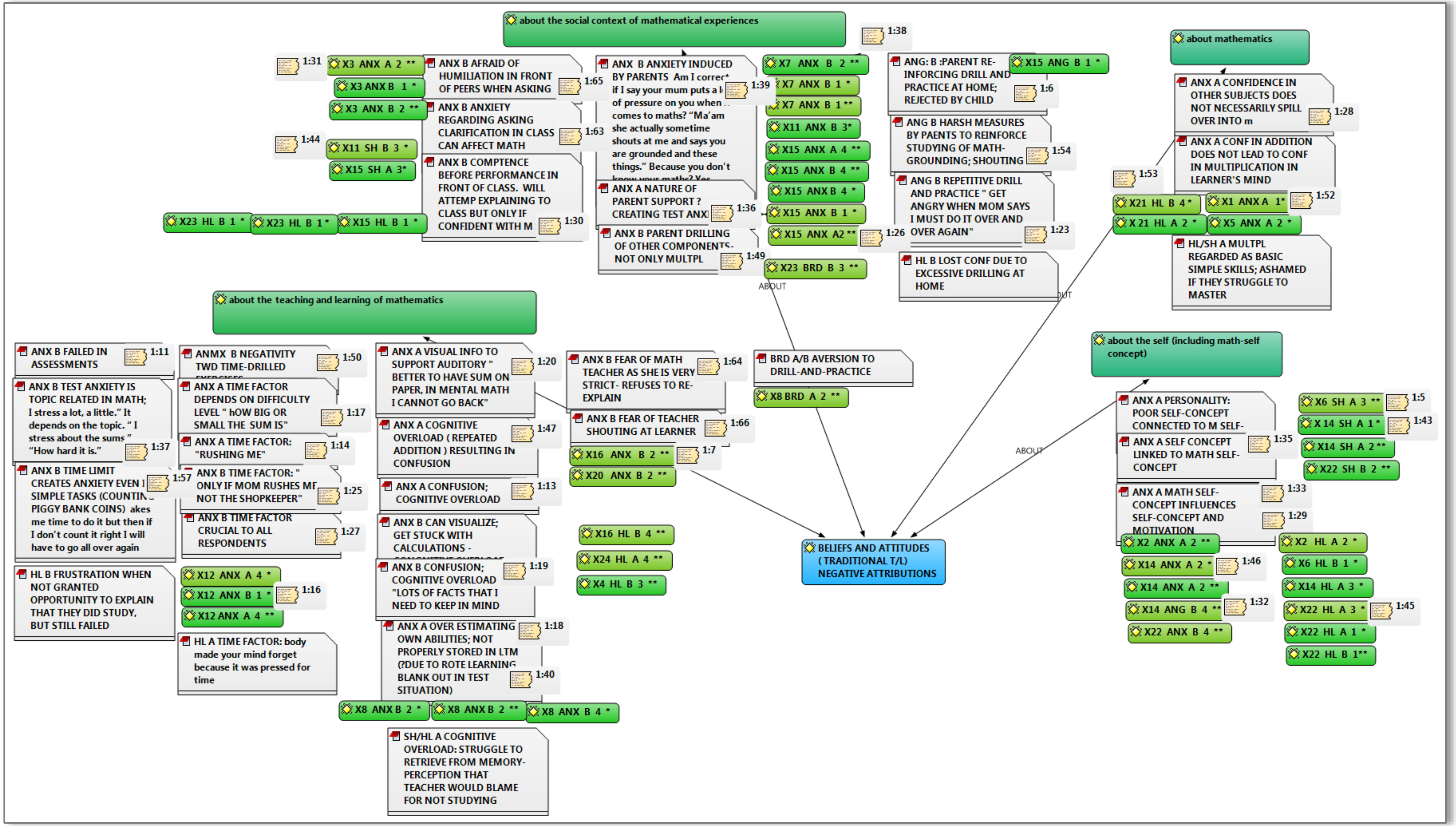


Figure 7.7a. Beliefs and attitudes (traditional learning environments): negative attributions

With regard to beliefs and attitudes about the ***social context of mathematical experience*s and the *teaching and learning of Mathematics***, negative attributions were in abundance when compared to the few positive attributions explained in this sub-section. Negative attributions were also made about *mathematic*s and *Mathematical self-concept.* The following reflections (reasons for *anxiety* as negative attribution) evolved:

***Reflections on the teaching and learning of multiplication skill*s:** The participants displayed an aversion to time-drilled practice of multiplication tables. Although a single participant declared that time limits are only troublesome when the difficulty levels are increased ["*how big or small the sum is'*] *[QU1:17] [par.23]*, the rest (5) of the participants agreed that time limits made them anxious: "*Ma'am pushes us, we are given a little bit of time to write all these different sums. Then your body says "O, I can't do it, I can't finish. Then… then you forget it." "So it is actually not you, your body made your mind forget because it was pressed for time?"* "*Yes ma'am." [QU 1:27][par.37]*

In addition, the participants also admitted to not being able to retrieve accurately from their long term memory when pressed for time (Ma, 1999; Wigfield & Meece, 1988). This resulted in confusion and frustration which, in turn, gave rise to *hopelessness* and *shame* as negative affect. Hopelessness: *"Because I studied, but then I got all of them wrong because I forgot them; I was too busy learning the other work." "But there is nothing you can do to proof it ma'am." [QU 1:41; QU 1:42] [par.58 & 64]. Shame*: *"I didn't really know the answer ma'am"…* "*I didn't really know how to count in sevens." [QU 1:5] [par.8].*

The participants also indicated lacking learning and teaching support (and support materials) when taught how to automatize times tables' facts. According to the participants, overt reliance on verbal input without visual support that resulted in cognitive overload was encountered in conventional classroom and home teaching and learning environments. Learners were not yet ready to rely on rote memorisation as they still struggled to count in intervals because this pre-requisite skill to automatisation has not been reinforced yet. These findings correspond with the research findings of Baroody (2006). Wong and Evans (2007) also explain that without automaticity a learner's focus will remain on applying computational strategies rather than attending to the problem solving task at hand – obviously slowing problem solving processes down and resulting in learners complaining about: "…*better to have the sum on paper; in mental mathematics I cannot go back" [QU 1:20] [par.27]* "*I have to go what's this, what's this because I have to count on my fingers I was like 5, 10, 15, 20, 25 and then some days I get stuck like I know the answer in my head somewhere and then, but you can't think of it ma'am."[QU 1:47][par.69] "Because there are rows and apples and everything but because I had to count everything I'm going to get a little confused. So I try to see the picture but the problem is that the calculations are difficult." [QU 1:49][par.70]*

Sprouting from abovementioned anxiety experiences, feelings of shame and hopelessness once again manifested*: "…some days I get stuck like I know the answer in my head somewhere and then, but then I can't think of it ma'am." [QU 1:47] [par.69].*

It was not only during learning of multiplication skills, but also during the teaching thereof that participants felt unsupported. They experienced their Mathematics teacher as very strict and unapproachable: *"…sometimes I don't understand the question and I go ask the teacher and they say I explained once and I am not going to explain again." [QU 1: 64] [par.89].*

Feelings regarding past (and ongoing) negative experiences (failure) in assessment tasks were also expressed: the participants admitted to failure in assessment tasks on specific Mathematics curriculum content areas. *"I stress a lot or little; it depends on the topic". [QU 1: 37a] [par. 54].* It also became clear that participants were anxious about the difficulty level of learning content as they related it to past failures with difficult content and despite having studied they contemplated that they would still fail the assessment "*I stress about the sums. How hard it is. I can only concentrate when I don't have anyone by me." [QU 1: 37b] [par. 54].*

The abovementioned attributions culminated into feelings of hopelessness as expressed in the following quotations: *"They [teachers] ask different questions and instead of the questions that you know… Yeah that you thought you knew!" [QU 1: 40] [par. 57]. "She [teacher] took the test from me as I was struggling and said I did not study. I would get like really upset and annoyed inside but outside I looked fine, because I knew it's not true. But there is nothing you can do to proof it ma'am. There is nothing you can do to proof it." [QU 1: 41] [par.58].*

Reflections on the social context in which computational fluency is to be attained*:* The participants displayed fear of being humiliated in front of peers. Two participants were clear about not asking for clarification in class when they do not understand due to fear of humiliation. Neither were they prepared to demonstrate a skill that involves multiplication in front of the class as they do not yet feel competent and confident. *"I am scared that I will look like a fool. After what happened at my other school I started hating it." [QU 1: 65] [par. 89]. "No not really ma'am, it is not really my thing but if can be confident in long division then I will do it and get it over and done with". [QU 1: 30] [par. 40].*

The nature of parental support in automatising multiplication facts were also implicated: All of the participants admitted to rejecting the methods their parents use in supporting them. All parents resorted to drilled practice; either reciting times tables, "*Yes, but mom keeps on saying I must do it* (reciting 7 times table*) over and over and sometimes I get irritated and angry."[QU 1: 06] [par. 8]* or using paper-and-pen exercises: *"I write them down on a piece of paper and then I give them to my mom and then she says I must say some of them and if you get one wrong you go and do it over again until you get them all of them right."[QU 1: 23] [par.32].* Instead of re-teaching, parents resort to shouting and grounding when their children fail to master the skills: *"Ma'am I will be very nervous and I will be very lazy because ma'am she* [participant's mother] *says I didn't do it fast and ma'am when I do it fast I lose my concentration then I … give up all together. I give up just like that. Ma'am she* (mother) *actually sometimes shouts at me and says you are grounded and these things." Because you don't know your maths? "Yes ma'am*" *[QU 1: 27] [par.37*]. One of the participants reported that her parent's actions could have created test anxiety: "*I take it then that mom doesn't put pressure on you when it comes to maths tests* (prompt)". *"She sometimes does then I struggle a lot "[QU 1: 28] [par.28].*

Reflections on mathematics and mathematical self-concept: Confidence in other subjects were not necessarily transferred to mathematics: *"Ma'am I struggle with math; not even me and mom could get it right. We were spending the whole afternoon trying to figure out one sum, but ma'am with everything* *else ma'am I can get up there and look like I am on top of the world and I can say speeches in Afrikaans, English… anything except math" [QU 1: 28] [par.38].*

Confidence in other computational skills were not transferred to multiplication skills: *"Ma'am mainly because I have to go what's this, what's this? Because I have to count on my fingers I was like 5, 10, 15, 20, 25 and then some days I get stuck like I know the answer in my head somewhere but I can't think of it ma'am. But with addition… I know all my addition sums because I do it every single day. For 3 years now from Grade 1 I am fluent in addition" [QU 1: 53] [par. 73].*

An overall positive self-esteem did not guarantee a positive mathematic self-concept: *"Ma'am sometimes I want to jump off my chair and jump and say what the number is, but then I get cross for not finding the answer in my head" [QU 1: 45] [par. 67]."Ma'am with everything else ma'am I can get up there and look like I am on top of the world and I can say speeches in Afrikaans, English anything except math. When the teacher asks me to explain to the class I will want to cry" [QU 1: 29] [par. 39].*

A poor mathematic self-concept negatively impacted on participant's self-esteem and resulted in poor motivation: *"Learner D you take part in eisteddfods, but you don't like performing in front of the class…explaining a sum to them?" "Nope." "Not at all?" "After what happened at my other school I started hating it" [QU 1: 32] [par. 44]. "Ma'am in case I know the sum and then the next thing I forget it and then the class laughs at me" [QU 1: 33] [par. 45]. "When I get stuck I just sometimes want to scream and say help me and then I go like: what is wrong with my head?" [QU 1: 46] [par. 68].*

- *Positive attributions*

Literature repeatedly revealed that academic emotions such as anxiety experiences reflected in the title of this study, should not be studied in isolation and that the counterbalance positive academic emotions together with the co-existing negative emotions should be studied in conjunction before attempting to draw conclusions (Pekrun et al., 2002; 2011; Villavicencio & Bernardo, 2013; 2015). Positive attributions, as counterbalance to negative attributions that emphasised *anxiety* will henceforward be described.

Analysis of the focus group interview data revealed positive attributions (feelings of *confidence* and *pride)* about the self and about teaching and learning of Mathematics. Figure 7.6b illustrates the domains from which *pride* and *confidence* as positive attributions evolved. A discussion of each domains now follows.

Reflections on the social context of teaching and learning mathematics: Participants reflected on the confidence that learning as part of a social group created. *"Because if I don't understand I will read it over and over, then I will remember, but if I don't remember I can just ask someone next to me" [QU 1: 60] [par. 84].* One of the participants reflected on the teacher's role in teaching and learning; contemplating that learners can be confident at all times. If learners should fail to succeed, teachers were the only ones to blame: *"Ma'am as a maths teacher you have to explain to a child that does not now, because otherwise you are not actually teaching maths. If you fail the test you can go back and say to the teacher that it is her fault, because she didn't explain to you" [QU 1: 61] [par. 86].*

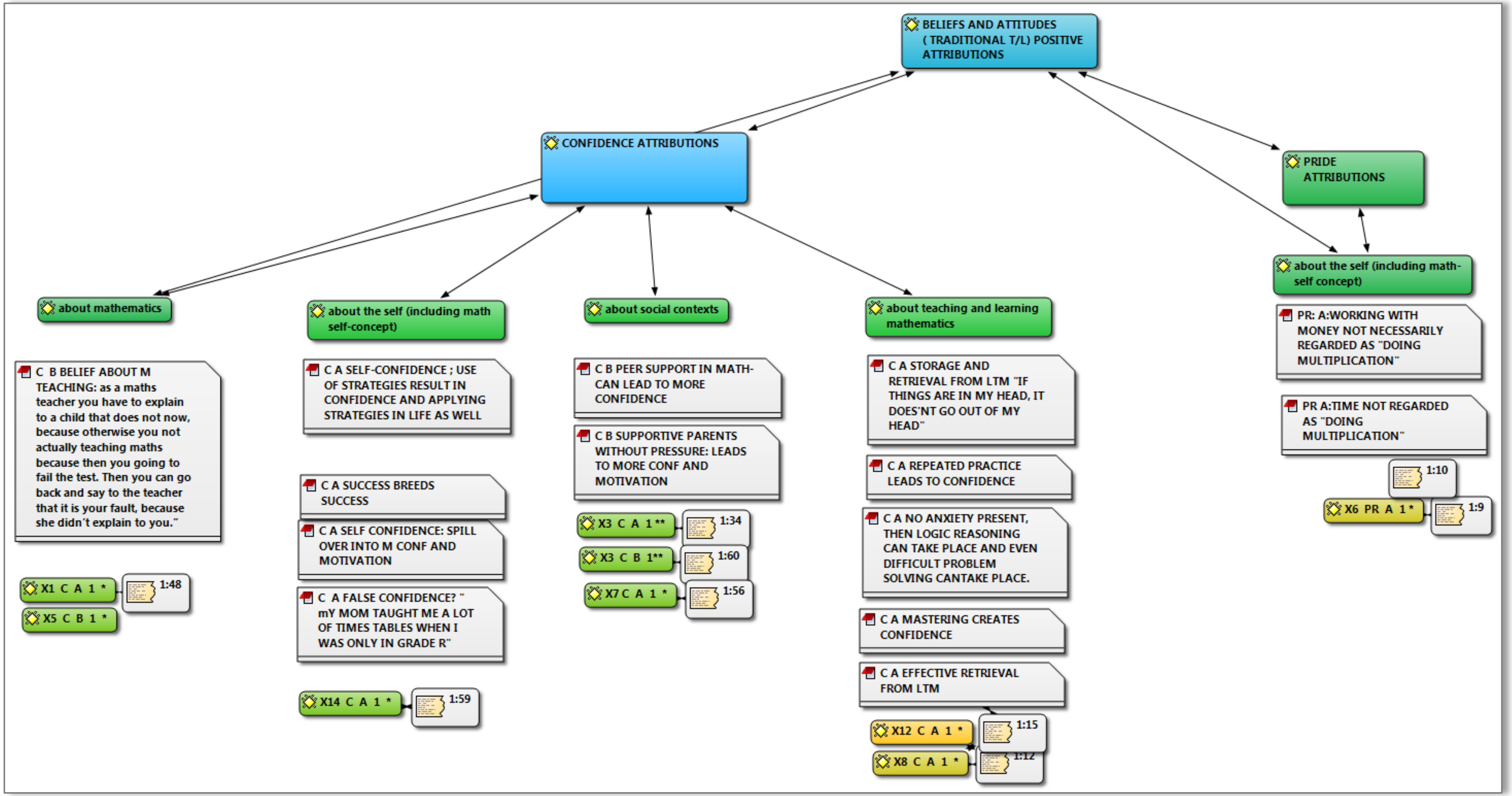


Figure 7.7b. Beliefs and attitudes (conventional classroom and home teaching and learning environments): positive attributions

Reflections on the teaching and learning of multiplication skills: The participants reflected on the value of repeated practice of multiplication facts as they contemplated that practice would lead to improved storage and retrieval from long term memory. One of the participants displayed such confidence that she contemplated practicing memorising multiplication facts from grade 1 at school whereas multiplication is only introduced during the latter half of grade 2 curriculum. (DoBE, 2012). False confidence could therefore also present. *"Ma'am because it is very easy ma'am because I know them all in my head ma'am." "Do you know all your times tables?" "From grade 1 ma'am because I learn it and learn it, it is things in my head that it doesn't go out of my head" [QU 1: 21] [par. 30]. "It's easy ma'am! I'll pick two sums that have a zero in it because everything times 0 is 0! [QU 1: 15] [par. 23]. "Ma'am I am not nervous ma'am it's very, very easy to do long division, it is just like answering like a couple of questions very, very easy multiplication questions." "So can you follow the steps of long division?" "Yes ma'am, one by one." [QU 1: 34] [par. 47].*

Reflections on mathematics and Mathematical self-concept: Regarding situations where learners were not yet competent or fluent in multiplication facts, a participant commented on coping skills to improve own math self-concept: *"Ma'am I can't really work with money ma'am but I will first count the money and then go and stand in the queue." [QU 1: 59] [par. 83]* (Participant explained that she would refrain from entering a situation where mathematical solutions were demanded; bided time to find answers first). Another participant did not regard working with time and money as applying multiplication skills. In this way the anxieties that multiplication usually created, waned. When success followed, feelings of self-worth and even *pride* were displayed: *"Ma'am because two R5's equals R10 and two 50 cents makes R1 and another two 50 cents makes another R1 and that equals R12."* (Using doubling with confidence in context of money; not realising the connecting with 2x table) *[QU 1: 09] [par. 12].*

A discussion of findings on the same participants' *anxiety↔confidence* experiences (in relation to other positive and negative academic emotions) while automatising multiplication facts in computer-assisted (CAI) learning environments follows.

7.3.2 Synthesis of findings: Phase 2A

Research sub-question 4 informed the observations that took place during this phase: To understand to what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home learning environments during the automatisation of multiplication facts? The goal of answering this sub-question was to observe the participants' anxiety experiences (if any) that could be associated with prior learning of multiplication facts, the conventional learning environment in which these skills were acquired, participants' mathematics self-concept at the point in time and participants' attitudes and belief regarding mathematics. The researcher had to be aware of possible anxiety experiences and the extent thereof with which participants' would enter the unfamiliar CAI environments during the gameplay sessions that followed. The findings (briefly stated) were:

- Participants provided accounts of emotional experiences that could be related to not only *anxiety*, but also to *confidence* experiences. Participants' recalled *anxiety* experiences that were observed to be in trait ('chronic') position, were more frequent than *anxiety* experiences in state (acute) position. *Confidence* experiences were only observed in state position.

- Some of the observed *anxiety* experiences were self-constructed, but the majority originated in social contexts that were associated with the teaching and learning of multiplication facts – with the Mathematics classroom situation and parents' so-called inflexible ways of supporting participants in the automatisation of multiplication, were singled out as stressors.
- The teaching strategies used by participants' Mathematics teachers were also observed to be inducing *anxiety*: time-drilled practices, rote memorisation and metal math 'tests' were mentioned.
- Although self-constructed confidence experiences were observed, on closer inspection the "*confidence*" could have been due to self-reported and invented coping strategies to combat their own *anxious* feelings. Subsequently, evidence was also found that by resorting to coping strategies participants actually derailed themselves, resulting in more *anxiety* experiences.
- No *anxiety↔confidence* experiences were attributed to positive or negative beliefs and attitudes towards mathematics as scientific disciplinary field.
- Participants' outcome focus was not clouded by *anxiety* experiences (up to point in time) as no task avoidance behaviours could be tracked.
- Although a single data source was analysed, a distinct pattern between the prevalence of *anxiety* experiences, followed by *shame* and *hopelessness* in close proximity, was found.

7.3.3 Findings Phase 2B: participants' anxiety↔ confidence experiences in Computer Drill and Practice (CDP) learning environments

Data collection for analysis of participants' *anxiety↔confidence* experiences in CDP learning environments comprised of CDP gameplay recordings (non-verbal account), participants' individual post-gameplay reflections (verbal account) and the researcher's observational field notes captured as memo's on AtlasTi. In contrast with the limited field notes on the focus group interview, the researcher as inside observer during gameplay sessions, had been in a position to record more observations that could be added to memos during the analysis process. The analysis findings will also be set out according to abovementioned distinction:

7.3.3.1 Findings: observed anxiety↔ confidence experiences during gameplay

Gameplay data were analysed in a 'non-scientific' manner when compared to the findings that Human-Computer Interaction (HCI) software could yield on non-verbal indications of anxiety and other emotions. The manual coding process used in this study could be prone to many errors in interpretation.

Following research contributions were made by Pekrun et al. (2011) who explain that, *anxiety* is made up of uneasy and tense feelings (*affective component*), worries (*cognitive component*), impulses to escape from the situation (*motivational component*), as well as peripheral activation (*physiological component*) the conceptual framework (described in Chapter 2, sub-sections 2.4.2 and tabulated in Appendix A) was compiled from a variety of research findings on the topic and applied in analysing participants' observed *anxiety↔confidence* experiences. Navarro and Karlins (2008) stresses the fact that the *physiological* and *motivational* components of anxiety are conveyed through human facial expressions, gestures, body movements, postures and vocal interjections. These non-verbal modes of participants' communication during playing Smartygames (Sg) were observed, recorded and annotated.

Figure 7.7a displays the network view compiled for confidence experiences while Figure 7.7b illustrates the anxiety experiences while playing Sg. The reader is referred to Chapter 5, Table 5.5 to recap on the interpretation of the codes used in these network views.

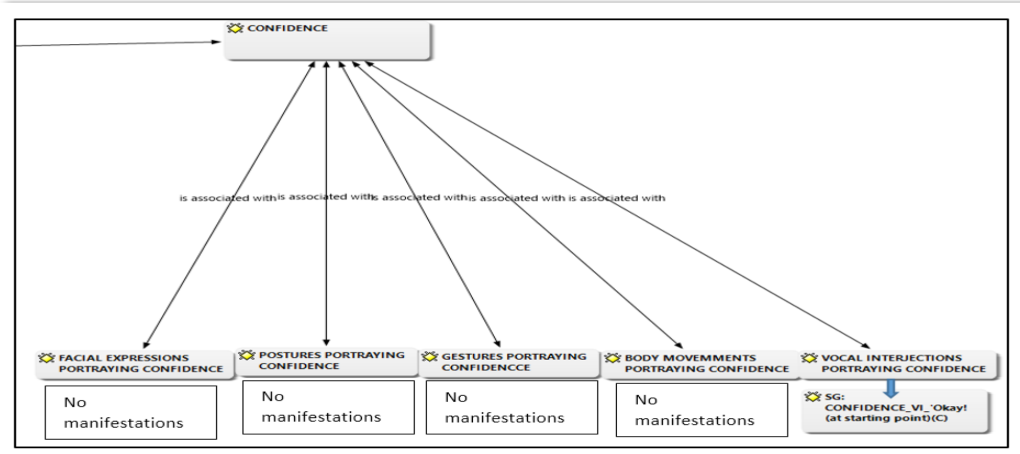


Figure 7.8a. Observable confidence experiences while playing Smartygames (Sg)

Figure 7.8a displays that only participant (C) displayed an observable indication of *confidence* and only at the very start of the game, not beyond. *Anxiety* experiences (as depicted in Figure 7.8b) are numerous. To enhance sense making, the co-existing negative feelings of *shame*, *hopelessness* and *boredom* and co-existing positive feelings of *pride* and *enjoyment*) were organised by means of Table 7.4a and 7.4b following Figure 7.8b on the next page. The reader is referred back to Chapter 5, Table 5.7 that sets out the coding process used while annotating the non-verbal data (video footage of gameplay).

To provide a holistic view of all the observable academic emotions while playing Smartygames, the total number of observed manifestations of academic emotions were tallied per category and a graphical representation was compiled to illustrate the Smartygames gameplay findings in chart format. Figure 7.9 displays this chart. This chart did not serve to provide statistical information, but it merely assisted in comparing CDP domain with that of DGBL domain – examining similarities and differences to derive findings only about the *confidence* ↔ *anxiety* experiences in comprehensive manner.

The edited video footage of the gameplay sessions of each of the participants can be accessed as .AVI file format on the enclosed CD or other storage device.

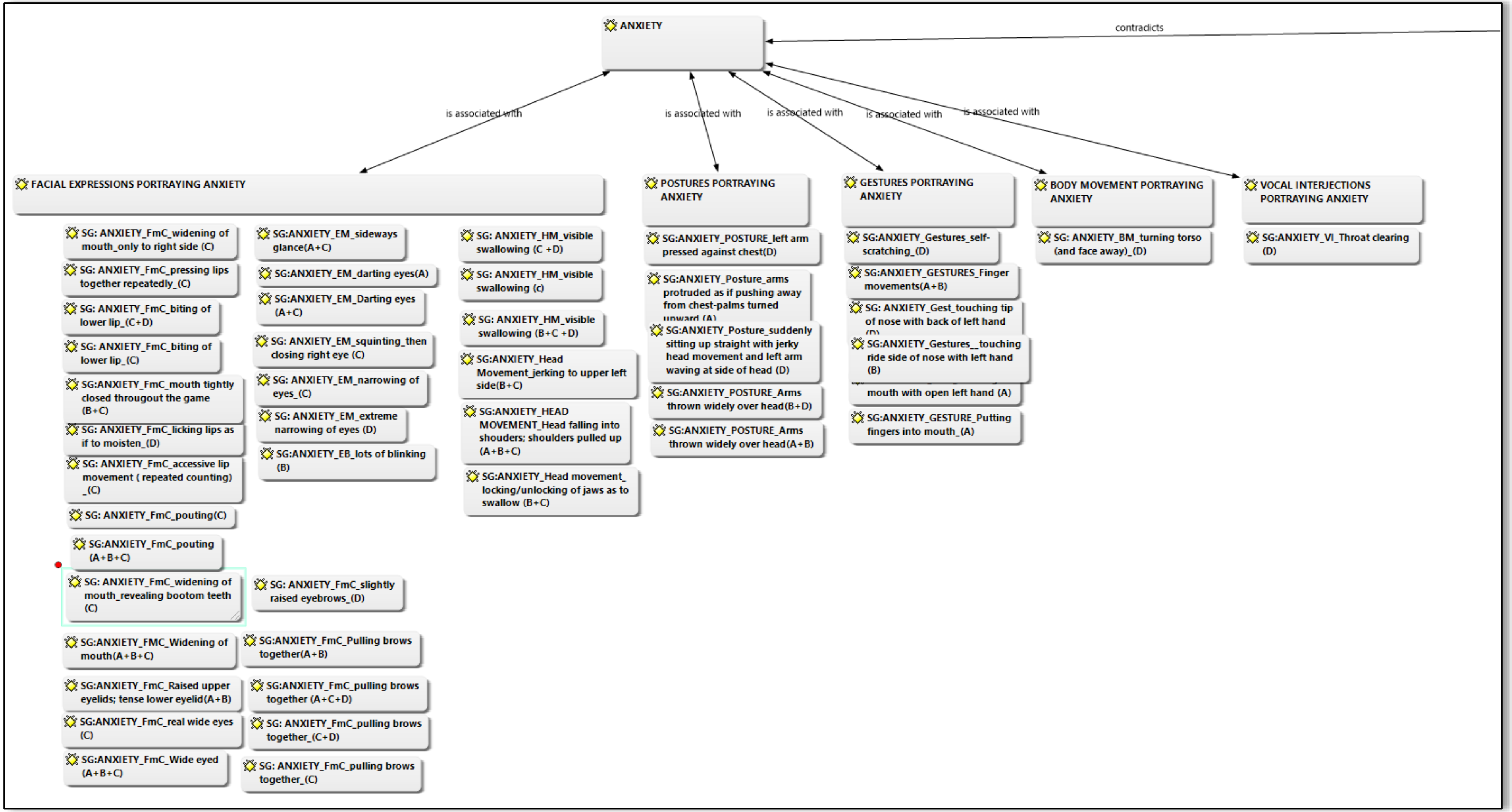


Figure 7.8b. Network view of observable anxiety experiences while playing Smartygames (Sg)

Table 7.4a. *CDP learning environment: Summary of observed facial expressions, gestures, body movements, postures and vocal interjections associated with shame, hopelessness and boredom as complementary emotions to ANXIETY.*

	FACIAL EXPRESSION			**POSTURE**	**GESTURE**	**BODY MOVEMENT**	**VOCAL INTER-JECTION**
	Facial muscle contractions	Eye movement & blinking	Head movement				
Hopelessness	Poker face (no contractions)		Gently shaking head	Slouch in chair		Passive (no movement)	Deep sigh
Shame	Downward glance				Twitching hand movements	Turning entire body away as if leaving	
Boredom	Nose pulled up-all wrinkled			Slouching and leaning into screen			

Table 7.4b. *CDP learning environment: Summary of observed facial expressions, gestures, body movements, postures and vocal interjections associated with enjoyment and pride as complementary emotions to CONFIDENCE.*

	FACIAL EXPRESSION			**POSTURE**	**GESTURE**	**BODY MOVEMENT**	**VOCAL INTER-JECTION**
	Facial muscle contractions	Eye movement & blinking	Head movement				
Enjoyment	Confident smile Smile		Nodding head while smiling				
Pride					Punching upward with clenched fist		
Relief							

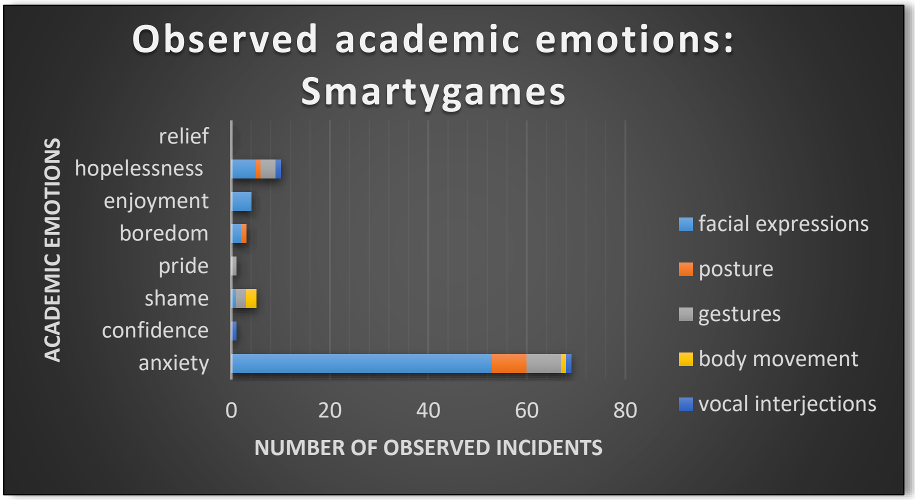


Figure 7.9. Summary: frequency of observed academic emotions while playing Smartygames (Sg)

Although the manually tallied manifestations of *anxiety↔confidence* and complementary secondary emotions as depicted in the figures (Figures 7.7b and 7.8b as well as Tables 7.4a and 7.4b) cannot be regarded as a flawless scientific endeavour, the trends that surfaced from the data analysis are still relevant: During CDP (Sg) gameplay almost 70 times more manifestations of *anxiety* were recorded in comparison with manifestations of *confidence*. In fact, only a single observable manifestation of *confidence* could be observed and recorded. *Confidence* could only be traced in a single voice interjection at the very beginning of the game. Other complementary positive academic emotions also manifested, but were limited to two incidents of facial muscle contractions (smiles) and a head movement (nod) that displayed *enjoyment.* A single gesture (upward punch with clenched fist) indicated *pride* while no indication that *relief* was experienced, could be observed. In retrospect, the researcher probably incorrectly interpreted the Participant' C's body language to portray confidence. Being observed the opening scenes of the game only, the experienced emotion was probably excitement (positive stress) as it was only observed momentarily and did not evolve into the participant displaying any positive academic emotion during the rest of the gameplay session.

The majority of observed anxiety experiences (53 out of 69) were conveyed by means of facial expressions – predominantly through facial muscle contractions. Figure 7.8b displays the full array of facial muscle contractions which includes lip biting, widening and tightening of mouth, pouting, widening of eyes, raised brows and pulling brows together. Whether these anxiety experiences could not be related top positive stress (coined "excitability" by Hackbarth et al., 2003) can only be revealed when interpreted in conjunction with the participants' personal accounts of their anxiety experiences as revealed through the individual post-gameplay interview data.

The total number of observed negative co-existing academic emotions (shame, hopelessness and boredom) were more than three times higher than observed co-existing positive academic emotions described in the previous paragraph. *Hopelessness* manifested more than *shame* or *boredom* and was conveyed not only through facial expressions (poker face, downward glance, wrinkled nose and gentle head shaking), but also by means of other bodily expression and vocal interjection. In this regard, manifestations of slouching in chair, passivity (no movement), twitching hand movements, turning entire body away as if leaving, slouching and leaning into screen and a deep audible sigh were observed. As players remained in seated positions, observations of facial muscles contractions (and to some extent also postures and gestures) yielded more data to be observed than other modes of body language.

The chapter now proceeds with an account of the findings derived from verbal data collected during post-gameplay individual interviews.

7.3.3.2 Findings: participants' anxiety↔confidence experiences as captured by post-gameplay self-reflections on Smartygames gameplay.

Table 7.5 provides a summary of participants'' reflections on *anxiety↔confidence* experiences and the aspects of the game that instilled *hopelessness* (as captured by means of the post –gameplay individual interviews with each participant). The discussion of the findings (of which Table 7.5 provides a summary) will commence after the presentation of the table.

Table 7.5. *Summary of self-reflections on anxiety↔confidence experiences as well as feelings of hopelessness: CDP games (Smartygames)*

	Reflections on CONFIDENCE experiences	**Reflections on ANXIETY experiences**	**Game aspects that left participants feeling HOPELESS**
Participant A	*" If there were 50 answers" [instead of 100]* [A: 85][22]	"*The smarty game because you try to drag it to the answer and you have these bunch of this questions that you need to answer then you like oh no I need to answer those too and then you get a little nervous and a little frustrated and then it just builds up inside you. Then you stop going."* [A: 7-9]	*"The Smarty game because you get frustrated when you can't find the answer."* Why couldn't you find the answer? *"Because everything is on top of each other and if you want to get it, it's hard."* [A: 3-5] *"Like if they* [answers*] were in like order not in order but if they were open, then I could answer them."* [A:83]
Participant B		"*Ma'am the smarty game*." "*Yes, but I was just like I am stressed for the time and my heart is beating so fast I was like how am I going to do this."* [B: 40-42].	*Because ma'am some of the times tables are very hard I just do the easy ones and I was like: Oh, no!"* [line 12] *"Then I was like: Oh my gosh! I was just going to stop 'cause I don't know them."* [Did you guess them?] *"I was guessing them"* [B: 13]
Participant C	*"Ma'am because it is all different like multiplication and then you must know all the answer so if you don't know it then you just have to try."* [C: 95-96]	*"Smartygames"…"A little* [stressed] *ma'am 'cause I knew some of my times tables but some of them I didn't know where the answer was supposed to go".* [C: 16-18]	*"Where I put the flash card that is where I think the answer is; but then it isn't and I lose time."* [C: 21] "*Because then I would have more time to say okay this is where this card goes and this is where that goes . So then I would have put the correct answer much more easier."* [C: 25-26]
Participant D		*"Stressed the most, the one where the blocks that you have to put it on the right place just like that." " Yes the smarty games- it is so horrible*."[D: 19 -20]. *"the timer that is like right there at you 'cause you look at the score and you look at the time and so it like clogs up your mind like hurry, hurry, hurry Now you are to tell yourself to hurry and not to think on what the answers are and you don't take the blocks and put them there take the block put them there 'cause your thinking come on N---- you have to get it you have to win."* [D: 38-42]	*"You knew the answers to them you cannot find little blocks there." "You couldn't draw from underneath the pile … unless you like double clicked a lot but that would waste time!"* [D: 23-24]

[22] Quotations from individual post-gameplay interviews for example [D: 38-42] refers to the quotation of participant D in lines 38-42 of the transcription of the interview. The verbatim transcriptions of these individual interviews can be viewed on the enclosed CD.

During the individual post-gameplay interviews, all participants were in accordance that Smartygames was the least enjoyable game and three out of four participants reflected that Smartygames (as example of CDP game) stressed them out more than DGBL games [A: 7-9] [B: 40-42] [D: 38-42].. Feelings of *hopelessness* were observed in all of the interviews and these feelings were attributed by all participants to the complicated interface design of Smartygames and not necessarily to the difficulty level thereof [A: 3-5] [A: 83][B: 13][C: 25-26][D: 23-24]. The countdown timer on the screen was found to be too prominent and the task was found too complicated for the time allowed to play each round.

In general, no feelings of *confidence* while playing the game was expressed. Participants unanimously declared that they became '*stressed*', overwhelmed and even despondent. Therefore possibility of the non-verbal manifestations of *anxiety* in the previous sub-section 7.3.1.1 being interpreted as "*excitability"* (positive stress) can therefore be ruled out rationally as the verbal accounts reflect negative stress (*anxiety*) and not "*excitability"*. Participant B even wanted to give up altogether. When probed during the interviews, three participants reflected that they do not have any trust in Smartygames as a learning tool [A: 83] [B: 13] [C: 21]. Participant C, however, remarked that when automaticity regarding multiplication skills has been attained (when learners "really know their times tables"), they will be confident in all games, irrespective of the skill level thereof. She contemplated that Smartygames would be the best "teacher" of multiplication facts as it would serve as the best assessment tool for a teacher; negating the way in which skills were taught [C:85-100].

Apart from investigating participants' ***anxiety↔confidence*** experiences participants' post gameplay reflections were also scrutinized against the conceptual framework (sub-section 7.2.1, Table 7.1) of Sweetser and Wyeth's (2005) GameFlow model for ENJOYMENT. Table 7.6 sets out reported *anxiety* and *confidence* with regard to: *concentration; balance between challenge and skills; clear goals and feedback; control, immersion* and *social interaction* as separate - overlapping aspects fostering gameflow resulting in ENJOYMENT. The summarised findings will be discussed after the presentation of the table (Table 7.6).

Table 7.6. *Participants' comments relating to anxiety↔confidence experiences during Smartygames gameplay as set out according to Sweetser and Wyeth (2005) GameFlow model.*

	ASPECTS OF SWEETSER AND WYETH (2005) GAMEFLOW MODEL OF ENJOYMENT: Participants' comments: Positive comments are indicated in green and negative comments in red				
	Focussed Attention	**Balance between Challenge and Skills**	**Clear goals and Feedback**	**Control**	**Immersion**
PARTICIPANT A		"*Because everything is on top of each other and if you want to get it, it's hard*" [A: 4-5]		"*you get frustrated when you can't find the answer"* [A: 3-4]	
PARTICIPANT B	*"I was just like I am stressed for the time and my heart is beating so fast I was like how am I going to do this. Oh no."* [B: 41-42]	"*some of the times tables are very hard, I just do the easy ones*" [B: 11-12]	"*Yes because I'll just go for the easy ones."*[B: 63]		
PARTICIPANT C	*"Ma'am because it is of all different like multiplication and then you must know all the answers. So if you don't know it then you just have to try."* [C: 96]	*"Because if like you don't know and it comes in the exams then you just going to get that question wrong."* [C: 89-90]	"I knew some of my times tables but some of them I didn't know where the answer was supposed to go." [C: 17-18]	"Where I put the flash card, that is where I think the answer is; but then it isn't and I lose time*"* [C:21] *"If we didn't played for time it would have been different"* [C: 24]	
PARTICIPANT D	"*You stop right there cause you look at the score and you look at the time and so it like clogs up your mind like hurry, hurry, hurry-you are tell you self to hurry*" [D: 39-40]	You couldn't draw from underneath the pile? "*No you couldn't unless you like double clicked a lot but that would waste time"* [D: 23-24]		"*You stop right there cause you look at the score and you look at the time and so it like clogs up your mind like hurry, hurry, hurry know you are tell you self to hurry*" [D: 39-40]	

The number of negative responses surpassed positive comments by more than half. From these comments it can be concluded that negative academic emotions (especially feelings of anxiety) derailed participants' ability to perform in the game (Participant B & D) as it interfered with their ability to concentrate on the learning goal of the game [D: 39-40]. On the other hand, participant C commented that as learners should have mastered times tables by the time that the gameplay sessions took place, the game mechanics of Sg. would have assisted in focussing attention of the learning goal of the game and should led to mastering of the content. As social "agent", the computer is therefore thought to foster positive social interactions [C: 96].

The skill level of Sg. in relation to the time allocation, was a major concern for three participants (A, B and D): it was found to derail the balance between skills and challenge that was to foster gameflow [A: 4-5] [B: 11-12] [D: 23-24]. Although the game and learning goals were clear, participant C felt that it was unattainable [C: 17-18]. Participant A admitted to the self-invented coping game strategy of only attending to easy sums [B: 63]. All of these aspects would, according to the gameflow model, inhibit flow in the game – therefore limiting (if not forfeiting) enjoyment of the game. Although two participants commented on the clarity of the goals as stated above [B: 63] [C: 17-18], no comments were made about Smartygames' ability to provide feedback in terms of the learning and game goals.

Three participants (A, C and D) also commented on the time-drill factor that made them loose control in and over the game [A: 3-4] [C:21][C: 24][D: 39-40].

No comments (negative or positive) could be related to Sg's potential to provide opportunities for players to become immersed in the game. Due this reason in particular, it can be concluded that Sg. did not promote gameflow and therefore also did not harness the power to be classified as "enjoyable" in a computer-assisted instructional environment.

The remainder of this chapter will consist of the exposition of the findings regarding anxiety experiences in a DGBL environment. Findings regarding both games that provided the learning environments for data collection (Am and TA) will be exposed simultaneously to enable contrasting and comparing.

7.3.4 Findings: participants' anxiety↔ confidence experiences in DGBL environments

Participants' *anxiety↔confidence* experiences as observed and analysed by the researcher (through examining the non-verbal data) will be attended to first. The findings regarding these experiences will be followed by analysis findings of the personal accounts of *anxiety↔ confidence* experiences as provided by the participants (verbal data).

7.3.4.1 Findings: observed anxiety↔ confidence experiences during gameplay

Following the conceptual framework on facial expressions, gestures, body movements, postures and vocal interjections associated with academic emotions (Appendix A), participants' reactions were recorded by repeatedly scrutinizing video-taped material of both Arithmemouse (Am) and Timez Attack (TA) gameplay; carefully annotating every possible facial expression, posture, gesture, body movement and/or vocal interjection. Figure 7.9a and 7.9b display these annotations in terms of a) confidence and b) anxiety experiences while playing Am and TA. The reader is referred back to Chapter 5, Table 5.7 that sets out the coding process used while annotating the non-verbal data (video footage of gameplay). These network views will be replicated in Appendix H and I respectively. To enhance sense making of the network views, the observed and recorded *anxiety* experiences (together with secondary negative co-existing feelings of *shame*, *hopelessness* and *boredom*), and *confidence* experiences (together with secondary, co-existing feelings of *pride* and *enjoyment*), the recordings thereof were organised in table format in Tables 7.7a and 7.7b.

Table 7.7a. *DGBL environments: Summary of observed facial expressions, gestures, body movements, postures and vocal interjections associated with shame, hopelessness, anger and boredom as complementary emotions to ANXIETY.*

** Observations indicated in bold were made with respect to TA*

	FACIAL EXPRESSION			POSTURE	GESTURE	BODY MOVEMENT	VOCAL INTER-JECTION
	Facial muscle contractions	Eye movement & blinking	Head movement				
Hopelessness					Lifted hands, palm to the front, stating: Halt, no more		**“Stupid troll!”**
Shame	Brief mouth shrug	Avoid eye contact with screen				Turning entire body away	‘Oh my gosh”
Boredom	Raising brows; Wide-eyed; Nose pulled up Nose pulled upward						
Anger	Brows pulled together Frowning with lips pressed together						

Table 7.7b. *DGBL environments: Summary of observed facial expressions, gestures, body movements, postures and vocal interjections associated with enjoyment and pride as complementary emotions to CONFIDENCE.*

	FACIAL EXPRESSION						
	Facial muscle contractions	**Eye Movement & blinking**	**Head Movement**	**POSTURE**	**GESTURE**	**BODY MOVEMENT**	**VOCAL INTER-JECTION**
Enjoyment	Relaxed real wide smile Mouth slightly open Smiling+ widening of eyes + raised brows relaxing mouth muscles, slightly parting lips widening of eyes + cheerful smile slight smile while counting widening of eyes + slight smile ***relaxing mouth muscles to open mouth*** ***Smiling***		Nodding twice ***Nodding head***	Body erect, head upright		Gently swaying from side to side ***Repeatedly leaning into screen and moving away gently*** ***Swaying from side to side in chair*** ***Leaning into screen***	
Pride	Real big smile	***Alert and wide-eyed***	***Tilt head backwards*** ***Head held more erect than usual***	Sitting up straight + broad smile			"Oh, yeah!" ***"Yes!"***
Relief	Eyes almost closed with big smile Eyes narrowing, nose wrinkled while smiling	***Comfort-able blinking***			Licking lips to relief anxiety encountered ***Touching right side of nose with left hand*** ***Moistening of lips with tongue*** ***Bring finger to lip***		Audible sigh of relief **"Phewww!"** ***Soft sigh "phoof!" +audible exhale***

** Observations indicated in bold italics were made with respect to TA*

Although the manually tallied manifestations of *anxiety↔confidence* together complementary secondary emotions as depicted in the figures (Figures 7.10a and 7.10b as well as Tables 7.7a and 7.7b) cannot be pronounced scientifically correct and bias-free, the *trends* that surfaced from the data analysis are significant to describing participants' anxiety↔confidence experiences. When the total number of observed manifestations of academic emotions were tallied per category per game, graphical representations could be drafted to display the DGDL gameplay findings in chart format. Figures 7.9a and 7.9b display these charts.

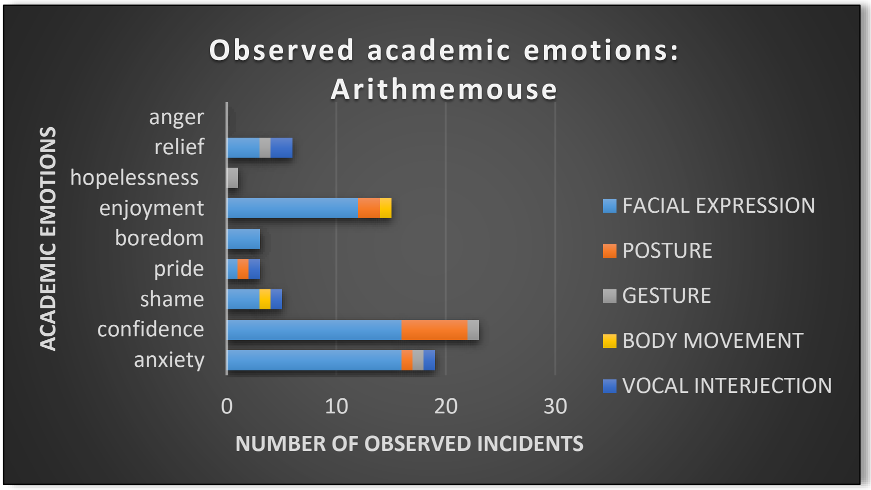


Figure 7.10a. Observed academic emotions while playing Arithmemouse (Am)

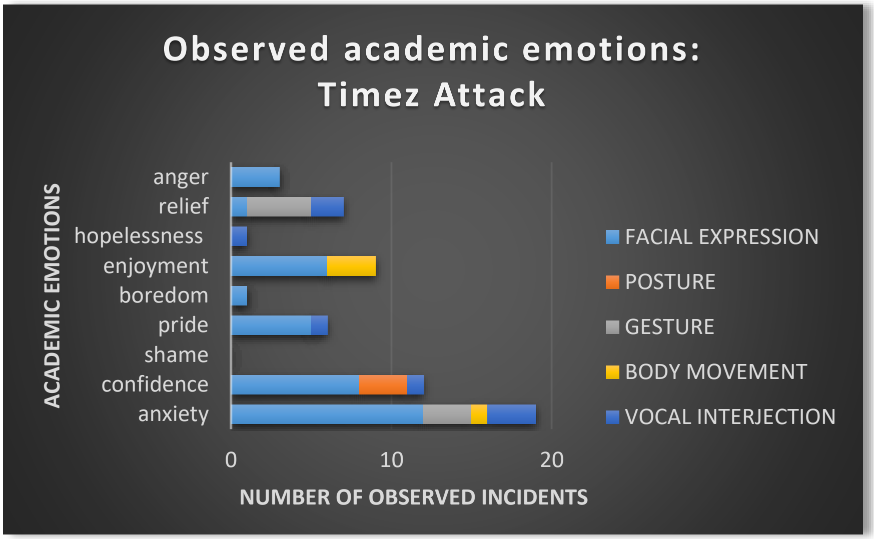


Figure 7.10b. Observed academic emotions while playing Timez Attack (TA)

When the analysis results displayed in Figures 7.10a and 7.10b as well as Tables 7.7a and 7.7b are studied in relation it can be inferred (despite all challenges encountered) that during DGBL gameplay: The total number of manifestations of *anxiety* were equal with respect to both games, but the modes of expression differed. During TA gameplay *anxiety* could probably not been expressed by means of posture; and body movement were possibly applied instead. During Am gameplay, it seems as if gestures instead of body movements were favoured. Observations of TA gameplay probably also resulted in less facial expressions of *anxiety* than Am, although more gestures as well as body movements were observed as modes of anxiety expression. Vocal interjections were observed in both gameplay sessions, but were used more often during TA gameplay. When the total subjectively recorded *anxiety* manifestations with respect to both DGBL games are, however, compared to the recorded anxiety experiences encountered in the single game in the CDP learning environment, the subjectively recorded manifestations (also during 15 minutes of gameplay) decreased by approximately 80%. Although the tallying of the observed manifestations of academic emotions may not be accurate or scientifically accountable, a distinct difference between anxiety experiences in the respective game genres (CDP and DGBL) could be established. In terms of co-existing negative academic emotions to anxiety, namely *hopelessness, boredom, shame* and *anger*, manifestations during Am gameplay were double that of TA.

Nevertheless, manifestations of *anger* were found only during TA gameplay- according to the subjective observations of the researcher, neither Am nor TA gameplay sessions displayed any indication of *anger*.

The two different DGBL environments yielded significantly different findings with respect to *confidence*: participants' observable manifestations of *confidence* while playing TA were approximately half of that of Am. As the observed expressions of confidence were conveyed by means of facial expression and posture in equal proportions in both games, it can be inferred that Am created a gameplay environment that led to feelings of confidence on the part of the players. It was only when the observable co-existing positive academic emotions (*pride, enjoyment and relief*) were studied, contrasting findings were encountered and possible explanations for TA's seeming lower confidence inducing ability, could be explored: During TA gameplay feelings of *pride* were especially conveyed through facial expressions and when compared to that of Am gameplay, twice as many manifestations were found. In contrast to aforementioned results, it was found that participants' observable manifestations of *enjoyment* while playing TA were approximately half of that observed while the participants played Am. Both sets of manifestations, however, comprised of equal proportions of facial expressions and postures as modes of expression. Gestures also were used to convey *enjoyment* during Am gameplay whereas in TA, vocal interjections were applied. With regard to manifestations of *relief*, no significant difference in frequency or composition could be observed in TA and Am respectively. To verify and interpret abovementioned findings on anxiety↔confidence and co-existing academic emotions, participants' own verbal accounts of their own affective experiences during gameplay were consulted.

7.3.4.2 Findings: participants' anxiety↔confidence experiences as captured by post-gameplay self-reflections

Table 7.8 provides examples of participants' reflections on *anxiety↔ confidence* experiences and self-reflections on the co-existing academic emotions experienced. These reflections were captured during the individual post-gameplay, semi-structured interviews.

Apart from investigating participants' *anxiety↔ confidence* experiences through verbal modes of expression (Table 7.8), participants' verbal post-gameplay reflections on DGBL games were also examined against Sweetser and Wyeth's (2005) GameFlow model for ENJOYMENT to reveal *anxiety↔ confidence* experiences. Table 7.9 sets out these reported *anxiety* and *confidence* with regard to: concentration; balance between challenge and skills; clear goals and feedback; control and immersion as separate – all overlapping aspects fostering enjoyment. The discussion of abovementioned findings will commence after the presentation of Tables 7.8 and 7.9 respectively.

Table 7.8. *DGBL games (AM and TA): Examples of self-reflections on anxiety□ confidence experiences and co-existing academic emotions experienced*

	Reflections on CONFIDENCE experiences	Reflections on ANXIETY experiences	Co-existing academic emotions together with in-game attributions thereof
Participant A	“The mouse one …it teaches you how add it up and then you get another chance … instead of saying it is wrong and you lose a life…nothing happened when you made a mistake” (lines 13-15) …”doesn’t like frustrate you it just goes through the doors and when it gives you a sum you just have to count and it gives you time. (lines 63-64) ..”when you go to the stairs, when you jump you read it and you know the answer.” (line 99-100) “room that I was in, was pleasant to me” (line 48)	***“Cause of the sounds distracted me and the troll is like standing there but then you can’t see properly because I was not facing him properly.” (line 71) “Dungeon one ‘cause the sound like gets in my head and then it says: O, no something’s going to happen then you worry about all these things”.(lines 74-75)***	BOREDOM: “if you get it incorrect again you keep on going down, up and down up and down.” (lines 79-80)
Participant B	..”where you go up the stairs and they teach you the sums ma’am.” (lines 5-6) ..”ma’am I just go to the 5 and I just sit and I do it.” “Because ma’am it give you clues.” (lines 28-29)	***“Still ma’am because ma’am the dungeon one is a bit hard for me” (line 59) “Because ma’am I would just pass the doors without looking at the doors.” (line 47) “Ma’am I would just press another number instead of the right number.”(lines 52-53)***	**SHAME:** ***“Ma’am I am just going up and down and getting confused.” (lines 20-21)***
Participant C	“Ma’am because like it has the times tables in the beginning then I can see the answers and then when I get to the questions I remember which answers that go with it.” (lines 4-6) ”Do one times table at a time…because that is easier to give the answer”. (line 12) “Ma’am ‘cause I like the answer that is already there so I can just count like 1, 2, 3, okay…” (lines 30-31) “the lighter colours…less stressed” (lines 51 & 54) “Ma’am because the mouse is a nice game because like these times tables that you get to choose like if you don’t know the other times table you can go for the 5 or the easy ones.” (lines 80-83)	***“That one you have to remember and I am not good with remember.” (line 39) “The banging music and the troll coming out will make me forget everything.” (line 40) “Ma’am it would be easier because there are no sums that means no remembering.”*** **(line 47)** ***“But I practiced …but it was there, but I just couldn’t remember it” (lines 61-62) “Dungeon one is more difficult than the mouse one.” (lines 110-111)***	**SHAME** ***“I did know the answer but I just kept on putting the wrong answers.”(lines 70-71)***
Participant D	“I think it did because it’s like it give you that happier fun feeling” (lines 40-41) “You mainly saw the snow, clouds and stuff … that you could actually touch when you are on the block moving” (lines 66-68). ***“They kind of give you the answers and you picking it up through snails, like you pick up the snails and it counts for you then at the end it gives you the answer then really all that you have to do is memorise it so it is pretty easy” (lines 6-8) “Because it gives you the answer and because that troll asks you the question over and over again you eventually then memorise it ‘cause you have to sit there and think”. (lines 84-85) “It doesn’t ask you different questions it asks one question and you move on whereas the troll one it gives you this question and give you that question so it really gets your head thinking” (lines 89-91)“Yes you kind of just go with it and you learn.” (line 133)***	“I didn’t really like the mouse one anymore because I had to do 6, 7 and 8.” (line 4) “…just sat there and told yourself you know this you can get this right… and then you don’t …” (lines 55-56) “***Makes you feel like your trapped, locked inside ‘cause when you go into the place where they throw those snails, the door behind you closes it kind of gives you that horrifying horrible feeling” (lines 62-64)***	**HOPELESSNESS: “*Not really interested in it… me and math we keep our distances.” (lines 14-15) “No ma’am don’t. Don’t push me. Please I don’t want more maths.” (line 50)***

*reflections on TA are indicated in *boldface italics.*

The anxiety experiences revealed by means of the researcher's interpretations of the verbal accounts of the participants during the individual post-gameplay interviews, will henceforward be discussed:

- Anxiety experiences: Despite the same learning goal (automatisation of times table facts up to 12x table) of both DGBL games, a discrepancy between the anxiety experiences were observed. Anxiety with respect to TA will be explained first, following by that of Am:

Timez Attack (TA): Participants A, B and C seemed to experience pursuing the game goal in TA as *difficult* [C: 110-111] due the participants' (self-reported) skills not matching the challenge of the game [B: 59][B 47]. Taking the game developer's description of TA into account, it could be inferred why participants A, B, D and to some extent participant C as well, experienced that they could not remember the time-tables facts: Big Brainz (Pty) Ltd describes the game context of TA's as "*a dragon's cave moodily lit, with traps and monsters. The avatar* (Shrek-like character) *displays anxiety when faced with math [for example multiplication] problems, and jubilation when the player gets them right. The music fits well with the overall (somewhat dark) mood. At the end of the maze is a big monster (troll) who will force the player to get a whole bunch of times table facts correct, quickly,* [or be hit over the head with a baton] *and sent back into the maze."* (http://www.bigbrainz.com/Multiplication.php). In accordance with Dondlinger (2007), Ke (2008) and Habgood and Ainsworth (2005) insisting that the game context must be experienced as *pleasantly challenging* and full of *fun-filled moments,* it can be derived that at least two participants were due to the negatively experienced sensory stimuli [A: 71 & 74-75] [D: 62-64] hesitant to explore. This could have hampered their direct engagement in the game, because of situational interest (that was supposed to trigger individual interest) not raised due to the game context (especially the mystery and fantasy elements) being experienced as unpleasant (Garris et al., 2002; Gunter et al., 2007; Lepper & Cordova, 1992).

Whereas participant A and D found the auditory input disturbing, participant B elaborated on the visual effects (dungeons and the doors revealing the troll) and exclaimed that she "*would just pass the doors without looking at the doors*" [B: 47]. In all three cases it can be concluded that the rejection of sensory stimuli therefore led to limited curiosity which, in turn, failed to activate cognitive curiosity. This cognitive curiosity was ultimately supposed to trigger pursuing the learning goal Garris et al. (2002). In this regard Kronenberg (2016) stresses that learning (transfer of acquired automatisation skills as positive outcomes of the game's learning goal) only takes place *after* the game has been played. Players therefore need to be immersed by pursuing the game goal, in order to learn.

Participant C reflected on the negative effect of sensory overload impairing the functioning of her working memory: "The banging music and the troll coming out will make me forget everything" [C: 40]. It was also clear that at the point in time she was already doubting her own ability to memorise facts [C; 39, 47, 61, 62]. These reflections points to Mayer and Moreno (2003) perspective that educational game designer's biggest challenge lies in managing essential cognitive processing by reducing extraneous sensory overload. This should be achieved by releasing working memory space for processing the learning content – especially in players with reduced confidence in their own abilities to memorise.

From all participants' reflections on their anxiety experiences, the question could arise to whether the participants were not merely *excited*? Was it not perhaps positive stress? Were they really experiencing anxiety? The observed co-existing academic emotions of *shame* [B: 20, 21] and *hopelessness* [D: 14, 15 & 50] points to at least two participants' experiencing *anxiety* and not positive stress (Hackbarth et al., 2003).

Arithmemouse (Am): Participant D was the only player observed to display feelings of anxiety while playing Arithmemouse [D: 4, 55-56]. When these quotations are not examined with the context of the entire interview transcription and viewed in conjunction with the researcher's anecdotal notes on gameplay sessions, the responses of participant D could easily have been misinterpreted as feelings of frustration rather than anxiety. Although not observed as 'feelings of dread', some anxiety (not excitement) could be observed. The researcher recorded that participant D exclaimed that she aimed to beat the other participants at this game by putting up the highest score. The anxieties revealed was therefore extraneous to the game and brought about by her own desire to win. In the process, she made unforced errors by attempting to process too fast: *"…just sat there and told yourself you know this you can get this right… and then you don't …".* Reflecting on her so-called 'failures' in the third person is also significant, but the analysis thereof however lies outside the scope of this study.

- Confidence experiences: Due to the anxiety↔confidence valence, discrepancies between the confidence experiences with respect to gameplay experiences (TA vs Am) were anticipated:

Times Attack (TA): It was, once again, only participant D who revealed feelings of confidence while playing the game. No feelings of 'confidence' in automatising times table facts could be observed by analysing interview data provided by participants A, B and C . Although the revelations were in retrospect, it needs to be taken into account that participant D played TA immediately after the abovementioned so-called "failure" in Am. This context cannot be negated when analysing her *confidence* responses [D 6-8; 84-85; 89-91; 133]. All of these confidence experiences notably elaborated on TA's design criteria of reinforcement, retention and transfer of acquired skills and effective in-game feedback. Viewed against this background, it would not be possible to infer whether TA really made her feel confident in pursuing the learning goal, or whether (due to the fact that she did not pressurise herself to win), extraneous anxieties were removed she "…*kind of just go with it* (the game) *and you learn."* [D: 133]. Should other participants have had confidence experiences as well, the seemingly conflicting confidence experiences of participant D, could have been verified.

Arithmemouse (Am): The confidence experiences observed in the responses of all participants reflected the incorporation of following researched game design criteria that CAI games should demonstrate into Am (refer to Chapter 3, sub-section 3.2):

The *game context* with the friendly mouse avatar, the bright, cheerful colours of the interface design, the calm and slow pace at which the game characters moves about as well as the soft music seemed to instil feelings of confidence when pursuing the game and sub-consciously the learning goal as well [C: 4-6; 51,54] [D: 40,41, 66-68] [A: 48].

Interactivity: Participants (as quoted) elaborated on Am's characteristics that created *individualised* and *differentiated* learning opportunities (Gunter et al., 2007). Moreno and Mayer's (2007) pre-requisites for interactivity, namely *controlling, manipulating, searching* and *navigating* are well-supported by means of comments on Am's strategies of providing unlimited opportunities to correct mistakes through re-teaching a specific times table's facts and the aspect of not having to fear consequences should a player provide wrong answers. This creates a sense of *control* in and over the game which, in turn, creates *confidence* [A: 13-15]. *Manipulating, searching* and *navigating* were fostered by Am providing endless prompts by means of re-teaching [A: 99,100] [B: 5, 6, 28,19] [C: 4-6, 30,31] and providing choice with respect to the times table to be automatized [C: 12, 80-83]

Challenge: Song and Zhang (2008) view *challenge* as the core motivational element of games while Gee (2007) claims that the fact that players can be successful at a stage (level) before the ultimate goal is reached as highly motivational. In Am, according to the video footage, Participants A, B and C chose the times table that they were confident in to enter gameplay. This choice factor and the learning successes that followed instilled confidence in pursuing the game goal and the learning goal [C: 12, 80-83]. In a single response

Although Plass et al.'s (2014) cautioned that their research findings on emotion design need to be viewed as preliminary, the researcher nevertheless wishes to direct attention to what researchers like Plass et al. (2014) and Mayer and Moreno (2003) downplayed as 'seductive detail' in game design. In Am, for example, the mouse avatar's round face and the bright, warm interface colours correlate with research findings that a joint emotional effect between the use of round, face-like shapes of instructional agents (for example avatars) and the use of warm interface colours exist (Magner et al., 2014; Park et al., 2014; Plass et al., 2014 and Um et al., 2012). These researchers postulate that altered emotional designs can result in improved transfer of knowledge and skills as well as better motivation to learning. Um et al. (2012) attribute these learning gains to positive emotions facilitating processing abilities of both working and long term memory.

Table 7.9. *Examples of participants' comments relating to anxiety□ confidence experiences during BGBL gamely as set out according to Sweetser and Wyeth (2005) GameFlow model*

	ASPECTS OF SWEETSER AND WYETH's (2005) GAMEFLOW MODEL OF ENJOYMENT:				
	FOCUSSED ATTENTION	**BALANCE BETWEEN CHALLENGE AND SKILLS**	**CLEAR GOALS AND FEEDBACK**	**CONTROL**	**IMMERSION**
PARTICIPANT A	*"You try to concentrate but you couldn't get everything out in the dungeon one" (lines 69-70)*	"Nothing happened you just go on… you can always get another chance because that's what they give you" (lines 17-18) "It only taught you a specific times table at a time." (line 97)	"Because if you get it wrong you go down and it teaches you how add it up and then you get another chance instead" (lines 13-14) *"…it just says nope it's incorrect let's teach you the correct answer." (line 59)*	"Like you get stuck somewhere, but then you can't use this thing (arrow key controls) the whole time" (lines 42-43) "When you go to the stairs it says when you jump you read it and you know the answer" (lines 99-100)	"*Cause you need to search the castle, then have to find these passwords but then if you get the key and open you have find the snails and that is what I like and you have to through them and they give you the answer"(lines 24-27)* "...not like scary thing and it doesn't like frustrate you it just goes through the doors and when it gives you a sum you just have to count and it give you time." (lines 63-64) *"…the sound like gets in my head and then it says o no something's going to happen then you worry about all these things but the sum he is asking."(lines 74-75)*
PARTICIPANT B	"You go up the stairs and they teach you the sums ma'am." (line 6) *"Because ma'am I would just pass the doors without looking at the doors." (line 47)*		"I just go to the 5 and I just sit and I do it." Okay so the mouse game gave you clues." *(lines 28-29)*		*"The troll not really ma'am. A little bit but not really." (lines 22-23)*
PARTICIPANT C	Ma'am because that is easier to give the answer … it focuses your mind." (lines 12-13) *"…but it was there but I just couldn't remember it."(line 62)*	*"Dungeon one is more difficult than the mouse one." (line 110-111)*	"I can see the answers and then when I get to the questions I remember which answers that go with it." (lines 5-6) "…'cause I like the answer that is already there." (line 30)	"That one is easier because you just type the answer." *(line 30)*	"Mouse game has got lighter colours and nice music." (line 53) "Mouse one is … a nice teacher." (line 80)
PARTICIPANT D	But didn't the snow, clouds and the beautiful stuff could perhaps distract your attention from the game? "It could but you mainly saw the snow, clouds and stuff like a lot comes in the snow that you could actually touch when you are on the block moving." Okay so had to wait anyway? "Yes." (lines 66-69) *"It really gets your head thinking on what the math is and how the maths works" (lines 91-92)*	*"Because that troll asks you the question over and over again you eventually then memorise it" (lines 84-85)* *"I would prefer the troll one for the children because that would teach them a variety of things instead of just that one section." (line 96-97)*		"I will then probably prefer the mouse because if you don't really know the answer, you can count on the rocks like you skip zero and go 1, 2, 3." (line 32-33) *"You sit there and you're playing a game you're having fun and just while you're doing it your learning." (lines 132-133)*	"*Because in that one they kind of give you the answers and you picking up tough snails… it counts for you then at the end it gives you the answer then really all that you have to do is memorise it so it is pretty easy."(line 6-8)* *"The troll no that's fine" (line 9)* "It gives you that happier fun… *the dungeon makes you feel like your trapped locked inside cause when you go in to the place where they through those snails the door behind you closes it kind of gives you that horrifying horrible feeling*" (line 61-63)

Participants' comments: Positive comments are indicated in green and negative comments in red. All comments in italics refer to TA gameplay.

Paras and Bizzocchi (2005, p.4) reflect on *gameflow* by stating that "since games foster play, which produces a state of flow, which increases motivation, will ultimately support the learning process". Sweetser and Wyeth (2005) follows this statement by arguing that if an activity is not enjoyed it cannot be valued as play and therefore not as a learning game as well. The extent to which participants therefore positively commented on the DGBL learning games' power to harness Sweetser and Wyeth's (2005) pre-requisites for gameflow, would then indicate the potential of the respective games to facilitate teaching and learning. Participants were, however, not in agreement to whether TA and Am did display evidence of all flow elements:

Concentration: participants agreed on the Am to capture the attention of players in terms of game context as well as learning content. In contrast, participants felt that mainly due to the fact that TA utilizes mixed problems opposed to Am's 'one times table at a time', the skill level that was supposed to be demonstrated was too high [A: 69,70][B: 6,47][C: 12,13][D: 66-69, 91,92]. This phenomenon created anxiety on part of learners, which hampered their ability to concentrate on the task at hand.

Balance between challenge and skills: Two participants were of the opinion that Am held a perfect balance – that players were neither under- or over-challenged [A: 17, 18, 97] [C: 110,111]. They regarded TA as too difficult- mainly due to mixed problem types. Although the participant D was not successful during gameplay, she sensed that TA challenged players by raising expectations and challenged players at a level slightly above their ability at the point in time. This participant regarded this as positive and also holds the opinion that the troll could be a good teacher as it sternly reinforced content by means of repetition. To this participant TA demonstrated balance between skill and challenge, just as Am [D: 84, 85, 96, 97].

Clear goals and feedback: Participants A, B and C were in accordance that both games did set clear, unambiguous rules and that in-game feedback regarding learning successes were provided. It can however be added, that more positive comments were made on the way in which Am did go about in providing informal, non-intrusive, consequence-free feedback [A: 13, 14, 59][B: 28, 29][C: 5, 6, 30].

Control: Apart from a single aspect of Am (having arrow key controls instead of computer mouse controls) [A: 42, 43], all other comments about feelings of control in and over the Am game, were positive [A: 99,100][C: 38][D: 32,33,132,133]. Participant D however also commended TA as she was of the opinion that she could control the game (although not entirely successful), but the biggest gain was that a player can actually learn through it, while thinking he/she is 'only playing'.

Immersion: Participants were divided on this component. Participant A appreciated the visual entertainment of TA [A: 24-27] while rebuking the auditory (sound) effects [A: 74-75]. This participant however admitted to being immersed in Am [A: 63, 64]. Participant B did not comment on Am, but the troll was pointed out as a factor that kept her from becoming immersed in TA [B: 22, 23]. Participant C did not comment on TA, but pointed out that the sensory pleasing interface and sound effects of Am caused her to become immerged [C: 53, 80]. Participant D was divided in her own opinion about this flow component: She admitted to being intrigued by TA's plot and how it visually played out [D: 6-9], but also admitted to the fact that the sensory stimuli and mystery finally overwhelmed her and she felt "trapped" [D: 61-63]. This participant did not elaborate on own degree of immersion in Am but admitted to it being "happier fun" than TA. Both games were therefore found to hold the potential of immersion, but the outcomes depends on individual players, confirming the research findings of Brown and Cairns (2004) describing immersion as degrees of individual involvement in a game. It can be concluded that both TA and Am display the necessary gameflow components for enjoyment, but that appraisals need to be individualised in order to be valid.

7.3.4.3 Synthesis of findings: Phase 2B

The relevant research sub-questions that needed to be answered in this chapter were stated in the introductory section of this chapter (sub-section 7.1). Only the major findings will be captured in the current sub-section as it will be revisited in Chapter 8 in attempt to answer to the main research question. In accordance with the challenges of the qualitative case study design all derived findings, however, needs to be viewed as preliminary and not generalizable outside the context of the current study. The finding merely intend to constitute a "dewdrop in which the world…" (participants' anxiety experiences related to different contexts in which multiplication facts are automatized)…"is reflected" (Nieuwenhuis, 2007, p.76).

RSQ 5: ***How do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts?*** The following major findings were derived from analysing both verbal (interview data) and non-verbal (gameplay recordings) data sets:

- Anxiety experiences were portrayed by means of the entire array of body language expression modes. Analysis of the verbal data could reasonably confirm this finding.
- The verbal recollections of experiences that could be interpreted as *anxiety* experiences verified the observed non-verbal manifestations of *anxiety*. The latter were approximately 70 times that of the observed *confidence* experiences.
- Confidence in Sg as an assessment tool, was expressed by one of the participants. The gameplay was, however, described unanimously by all participants as the least enjoyable among the three games.
- Co-existing negative academic emotions were found: *shame, boredom* and *hopelessness* were probably expressed non-verbally, but only expressions of *hopelessness* could be found during analysis of verbal data.

RSQ 6: ***How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?*** The following key findings were derived from analysing both verbal (interview data) and non-verbal (gameplay recordings) data sets:

- Due to the different gaming environments of the two games, the findings derived were also distinctively different.
- The number of observed manifestations of anxiety experiences in both TA and Am (as revealed through analysis of the non-verbal data) correlated, but were only approximately one quarter of that of the CDPO game. The findings regarding the two DGBL games were, however, in contrast to that revealed by the verbal data: TA were pointed out to result in more and more severe feelings of anxiety than MA. It was only Participant D who admitted to being 'stressed' while playing Am, but it could be confirmed that these anxiety experiences stemmed from extraneous factors outside the game context and could not accounted for all the anxiety manifestations revealed non-verbally by all participants. Although one of the participants said directly that they also experienced anxiety while playing Am, the researcher was confronted with the issue of whether participant's bodies (facial expressions, gestures, a posture and a vocal interjection) did not perhaps communicate the anxiety experiences that the participants' were not prepared to admit verbally and rationally?

Although subjectively derived, the findings derived from all the different data sources analysed converged and pointed out that the CDP learning environment examined was more at risk with regard to inducing or aggravating existing anxiety experiences (relating to automatisation of multiplication facts) than the DGBL environments examined.

Chapter 8

Summary, discussions and recommendations

When tools become toys, then work becomes play. –
(De Koven, 2013)

8.1 Introduction

This study followed a multi-method qualitative research design to interpret the anxiety↔confidence experiences of participants during automatisation of multiplication facts in CAI environments. The researcher aimed to describe and interpret the research problem as it manifested in a sub-urban South African primary school by examining a small sample from a population (all Grade 4 learners at the research site). Different sets of verbal and non-verbal data were collected and analysed during two research phases as set out in Chapters 4 and 5. Chapter 6 presented the analysis findings of the first research phase whereas Chapter 7 presented the analysis findings of the second research phase. Chapter 8 sets out to triangulate findings in order to answer to the secondary research questions. The findings were then contextualised in terms of the theoretical framework where after possible explanations, challenges and recommendations follow in order to answer to the main research question namely: To what extent do Grade 4 learners experience anxiety in computer-assisted instructional environments during automatisation of multiplication facts?

8.2 Summary of the Previous Chapters

Chapter 1 served as an introduction to the research project by discovering the background to the research problem, as well as the intellectual conundrum against which the investigation took place. Chapter 1 furthermore provided a concise review of relevant literature on computer-assisted instruction (CAI) and role of affect in Mathematics education. Gaps in literature were exposed and databases, research-engines and some key constructs of the study defined. Thereafter the research questions, aims and purpose of this study, the research design and methodology as well as the research paradigms and perspectives were briefly stated.

The literature review in Chapter 2 commenced with explaining computational fluency and the importance of attaining automaticity regarding basic computation skills. Thereafter a theoretical-conceptual framework for this study was provided by viewing the research problem from three different perspectives: Mathematics education, Affect in Mathematics education and Technology (CAI). The overlap of these domains provided the lenses that structured the research: ‘affect’, ‘flow’ and ‘learning’. ACAT (Vandebrouck et al., 2013) provided a framework for studying integrated Mathematics education and technology constructs whereas Sweetser and Wyeth’s (2005) GameFlow model provided grounding for investigation into the constructs bridging the overlap between technology and affect in Mathematics education. The overlap between affect and Mathematics education domains was underwritten by Pekrun’s (2011) Control Value theory of Achievement Emotions. As umbrella framework, the EFM model for educational game design (Song & Zhang, 2008) sufficed as it provided grounding for constructs from each of the three disciplinary domains in question. Chapter 2 continued with literary findings on the role of affect in Mathematics education, exposing beliefs and attitudes and academic emotions, but emphasising learners' anxiety↔confidence experiences during teaching and learning of Mathematics. Psycho-physiological manifestations of academic emotions were highlighted as well. A section on computer-assisted instruction ─ comparing computer drill-and-practice learning environments with that of digital game-based learning environments ─ was followed by a review of literature on the influence of computer-assisted Mathematics instruction on affect. An exposition of inconsistent literature findings concluded Chapter 2.

Chapter 3 focussed on examining available literature on CAI to reveal and discuss the following underlying game design criteria essential to CAI game design: game context, situational interest, rule and goal structure, interactivity, challenge, immersion and feedback. The chapter proceeded with a section on emotional game design and concluded by displaying the interrelatedness between the identified design criteria, gameflow elements and the design principles of conventional classroom learning environments.

Chapter 4 commenced by stating the researcher's general assumptions, theoretical assumptions, philosophical aspirations as well as the paradigmatic lens through which this study was viewed. The chapter then outlined the research design of the first research phase (Phase 1) of which the aim was to prepare research instruments to be used as research tools during the second research phase (Phase 2). Due to the two different, yet concurrent processes and products, this phase was subdivided into Phase 1A and Phase 1B. Phase 1A sets out the research design whereby research sub-question 1 was answered. Interview statements and open-ended prompts were prepared by means of content analysis and the adaptation of Wu et al.'s (2012) SEMA instrument which was designed as research instrument to be used in quantitative studies. Phase 1B explains the research design which answers research sub-questions 2 and 3, that led to nominating appropriate CAI multiplication games (to be used as research tools during data collection in Phase 2). This process began with content analysis (as described in Chapter 3) and proceeded by conducting a qualitative survey during which the design criteria revealed by the content analysis, led to formulating open ended questions for a teacher's questionnaire and questions for a learner's questionnaire. The inductive reasoning process whereby the collected data were analysed, was also described.

Chapter 5 focussed the reader's attention on the core of the research endeavour: answering research-sub-questions 5, 6 and 7 that enabled the main research question to be answered: To what extent do Grade 4 learners experience anxiety in computer-assisted instructional environments during automatisation of multiplication facts? The research activities during Phase 2 comprised of two sub-divisions as well, Phase 2A and Phase 2B. Phase 2A focused on the research design whereby learners' anxiety↔confidence experiences as manifested in conventional learning environments were observed. The research instruments and methods of data collection and analysis whereby learners' anxiety↔confidence experiences in the CAI learning environments (CDP and DGBL respectively) were observed were then described in Phase 2B.

Chapter 6 provided the research findings of Phase 1A and Phase 1B. The analysis and synthesis processes whereby the final draft of the SEMA instrument was compiled were outlined as Phase 1A's findings. The chapter then proceeded by setting out the findings of Phase 1B. It explains how and why the pre-set requirement of nominating one game in the CDP learning environment and one game in the DGBL environment, was abandoned in favour of a single game in the CDP domain and two games in the DGBL domain to be used as research instruments in Phase 2 during gameplay sessions.

In Chapter 7, data collected from the focus group interview (Phase 2A), data from individual gameplay sessions and post-gameplay individual interview data (Phase 2B) were analysed. The analysis revealed findings that led to answering to the last three research sub-questions and eventually to the main research question as presented in sub-section 8.3 below.

8.3 Contextualising the Literature

Interpretations of the research findings allow the researcher to relate the subjectively derived findings of the qualitative researcher with the existing body of literature in the domain identified by the main research question (Mouton, 2012). Prior to the turn of the century, when the development of CAI games were still in their inception phase, researchers speculated on whether the use of CAI games could result in learners' heightened enthusiasm about, and engagement with Mathematics tasks and by doing so, counteract Mathematics anxiety (Nordin et al., 2013; Zhang, 2001). The studies that however produced substantial and valid findings were, in the opinion of the researcher, limited. The research findings of this study supported and contradicted findings of prior studies; referred to as the current body of knowledge on anxiety experiences during automatisation of multiplication facts by means of CAI. The researcher selected studies with substantial findings on at least two out of the current study's three major constructs, namely affect in Mathematics Education (emphasising anxiety); Mathematics education content (automatisation of multiplication facts) and computer-assisted instruction (with a clear distinction between CDP and DGBL environment). Table 8.1 displays these correlations and contradictions of the current findings to that of the selected prior studies. The table is laid out according to the chronological order of the date of publication – beginning with the most recent literature publications. The table is sub-divided into separate sections (8.1a – 8.1f), each putting forward the name(s) of author(s) and publication date; summary of the research problem and research design; major findings thereof; overlapping constructs with current study. The research sub-question(s) applicable to the context and findings from each literary publication is also indicated. A discussion of if and how the current research findings support or contradict the findings from literature concludes each contextualisation.

Table 8.1a. *Current body of knowledge: Correlations and contradictions (Boaler, 2015)*

Author(s) & Publication date	Problem statement/ Research Problem	Research design	Major finding(s)/ Conclusion(s)	Overlapping constructs
Research sub-question addressed: RSQ 4: How do Grade 4 learners experience anxiety in conventional classroom and home teaching environments during the automatisation of multiplication facts?				
8.1a Boaler (2015)	Research evidence on the best ways to learn Mathematics facts	Preliminary research report (working paper)	• Drilling without understanding is harmful: learners who learned primarily through rote memorisation might freeze during a moment of forgetfulness, and be unable to think through the problem and come to an answer efficiently. • Emphasising rote memorisation and time-drilled testing while attaining automaticity, can provoke Mathematics anxiety.	**1) Affect in Mathematics education**: ☑ **anxiety** ☒ other affect construct(s) **2)Computer-assisted instruction:** ☒ CDP learning environments ☒ DGBL environments **3) Mathematics teaching and learning content:** ☑ **Automatising multiplication facts** ☒ Other:
Do the current research findings support or contradict the abovementioned literature findings?				☑ **Supports**

Discussion: In answering research sub-question 4, it was shown that parents' time-drilled and rote learning (endless repetition by writing out times tables' facts) which were offered in 'support', created the most anxiety experiences. Thus confirming Boaler's (2015) second conclusion (column 4 above). In confirmation of Boaler's (2015) first conclusion; an aversion to rote memorisation, especially when coupled with time-drilled practices (as in weekly mental mathematics assessments) was displayed. While resolving feelings of anxiety rationally (calming themselves down), while simultaneously having to process information to produce answers, clearly resulted in cognitive overload, impairing the functions of participants' working memory.

Table 8.1b. *Current body of knowledge: Correlations and contradictions (Bochniak, 2014)*

Author(s) & Publication date	**Problem statement/ Research Problem**	**Research design**	**Major finding(s)**	**Overlapping constructs**
Research sub-question addressed: RSQ 4: How do Grade 4 learners experience anxiety in conventional classroom and home teaching environments during the automatisation of multiplication facts? RSQ 6: How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?				
8.1b Bochniak, (2014).	Is there significant difference in math fact fluency among those sixth-grade students who receive didactic mathematics instruction and those sixth-grade students who receive FASTT Math software instruction, as measured by a 2-minute drill performance instrument?	**Quantitative study:** quasi-experimental, non-equivalent control-group design was used with 2 groups of 20 sixth grade learners (approximately 11 years old)	Significant improvement for those students who used FASTT Mathematics instruction over conventional instruction. By adding a FASTT Math session to conventional lessons developing multiplication fact automaticity occurred more rapidly that with conventional classroom instruction alone.	**1) <u>Affect in Mathematics education</u>:** ☒ anxiety ☒ other affect construct(s) **2)<u>Computer-assisted</u>** <u>instruction:</u> ☒ CDP learning environments ☑ **DGBL environments** **3<u>) Mathematics teaching and learning content:</u>** ☑ **Automatising multiplication facts** ☒ Automatising addition/subtraction ☒ Other:
Do the current research findings support or contradict the abovementioned literature findings? ☑ **Partially Supports**				

Discussion: As the current study focussed on anxiety experiences in conventional learning environments opposed to DGBL environments, performance (improved fluency) was not measured. The current research findings, however partially support Bochniak's (2014) findings as it can be inferred that optimum gameflow in DGBL environments, could lead to optimal challenging of both the game and learning goals. In turn, these factors could result in improved fluency. In the current study (as opposed to the single research tool of Bochniak, 2014), two distinctly different DGBL games and game contexts were used as research tools. By interpreting the participants' contrasting gameflow experiences as a possible indicator of improved fluency, the current research findings demonstrate that the gaming context of a DGBL game is the main determinant in learning success. A participant's affinity towards a particular gaming context is highly individualised. It is therefore risky to draw conclusions from only using a single game context of the game, FASST Math, used as research tool.

Table 8.1c. *Current body of knowledge: Correlations and contradictions (Jansen et al., 2013)*

Author(s) & Publication date	Problem statement/ Research Problem	Research design	Major finding(s)	Overlapping constructs
Research sub-question addressed: RSQ 5: How do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts? RSQ 6: How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?				
8.1c Jansen et al.(2013)	Hypothesis: "*When children experience that they can solve the majority of math problems, their math anxiety may lower and perceived math competence may increase. Given the reciprocal relation between emotional experience of math and math performance, improvement of math performance is expected as well." (p.191)*	Quantitative experiment: pre-and post-test design. (n=207) in 4 different groups (1 control and 3 experimental groups) DGBL environment: Math garden	Practising math frequently at a learner's own ability level improves math performance, and that the experience of success stimulates this practice. Increasing success rate in automatising addition, subtraction, multiplication and division, consistently improves computational fluency – in CAI environment more than usual conventional instruction. Although there were no conclusive findings regarding anxiety, findings confirmed that CAI reduces embarrassing experiences with mathematics in a conventional classroom situation.	**1) Affect in Mathematics education**: ☑**anxiety** ☒ other affect construct(s) **2)Computer-assisted** instruction: ☒ CDP learning environments ☒ DGBL environments ☑ **collaboratively stated as CAI environments** **3) Mathematics teaching and learning content:** ☑ **Automatising multiplication and division facts** ☑ **Automatising addition/subtraction** ☒ Other:
Do the current research findings support or contradict the abovementioned literature findings? ☑ **Partially Supports**				

Discussion: In the current, qualitative study, improved performance in computation fluency was not investigated. Apart from this variable, Jansen's (2013) study was the only publication at the researcher's disposal that investigated the same constructs as that of the current study (Mathematics anxiety, CAI environments and automatisation of multiplication facts). Due to the different research designs applied, it was not peculiar when Jansen's (2013) study could not yield any conclusive findings about computational fluency successes said to lower Mathematics anxiety. The current research findings confirmed that a qualitative research design from an interpretivist stance, can be regarded more effective when describing anxiety feelings and draw conclusions. In the current study, it could be concluded that although CAI environments do not rule out anxiety experiences, it eliminates the anxiety experiences brought about by a fear of being humiliated in front of peers and teachers when failing to provide correct answers. Regarding this aspect, both studies confirmed that CAI – games (in adapting the game challenge to the skill level of the player), not only lessens the chances of being humiliated, but also grants the player the opportunity to make mistakes in "private", possibly lowering anxiety.

Table 8.1d. *Current body of knowledge: Correlations and contradictions (Hanson, 2012)*

Author(s) & Publication date	**Problem statement/ Research Problem**	**Research design**	**Major finding(s)**	**Overlapping constructs**
Research sub-question addressed: RSQ 6: How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?				
8.1d Hanson (2012)	"*The main purpose of this study was to explore the impact that learning within a motivational, self-paced, and self-evaluative CAI environment (DGBL game: Timez Attack) linked to teacher instruction can have students' multiplication mastery and self-efficacy*" (p.23)	Mixed – method design was followed. Experimental pre-test post-test research design was applied in quantitative part. The qualitative data analysed were collected from informal interview questions, and participants' written responses to open-ended questions from the pre- and post- tests. (sample: eight study class groups, aged between 6 and 11 years)	In the group playing Timez Attack, learners' level of multiplication mastery improved significantly after CAI intervention. Results from the post-test also revealed significantly higher self-efficacy beliefs, and reduced nervousness in learning multiplication facts amongst *some* respondents.	**1) Affect in Mathematics education**: ☑**anxiety** ☑other affect construct(s): **self-efficacy: enjoyment, motivation and engagement** **2)Computer-assisted** instruction: ☒ CDP learning environments ☑**DGBL environment (Timez Attack)** **3) Mathematics teaching and learning content:** ☑ **Automatising multiplication** ☒ Automatising addition/subtraction ☒ Other:
Do the current research findings support or contradict the abovementioned literature findings? ☑ **Partially Supports**				

Discussion: As in the previous study (Jansen et al., 2013), improved automatisation was not measured. The researcher acknowledges the findings regarding reduced nervousness when automatising multiplication facts amongst *some* respondents, but feels that the qualitative findings of the study should have pointed out why all the respondents did not experience reduced anxiety. In the researcher's opinion, Hanson (2012) focussed on the mastery goal of Timez Attack, overlooking the deeper problem that the game context of Timez Attack could have caused. According to the research findings of the current study, the learning content, feedback and the excellent matching of the game's challenges with players' skills, contribute to the success of the game in terms of automatic. When the surface of these performance successes are however perused, it is revealed that the game context is very likely to instil anxiety in players, thus derailing gameflow and possibly lowering the performance. Hanson (2012) therefore overlooked the important aspect of not only ensuring the challenge-balance, but even more importantly, ensuring that the DGBL game matched the personality and interest of the respondents as well.

Table 8.1e. *Current body of knowledge: Correlations and contradictions (Jones, 2011)*

Author(s) & Publication date	**Problem statement/ Research Problem**	**Research design**	**Major finding(s)**	**Overlapping constructs**
Research sub-question addressed: RSQ 6: How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?				
8.1e Jones (2011)	Determining the effects that a computer instructional game (Timez Attack) had on basic multiplication fluency, learner motivation, and student self-efficacy towards mathematics.	Quantitative experiment: pre-test/post-test design with 70 (8-9 year old learners). Timez Attack gameplay sessions were the '*intervention'* according to the research design. Administering a teachers' survey provided data on the motivational changes of the respondents.	· Significant increase in computational fluency in multiplication and division. · No increase in conceptual understanding. · Increase in student motivation for learning mathematics	**1) Affect in Mathematics education**: ☒ anxiety ☑other affect construct(s): **self-efficacy: motivation** **2)Computer-assisted** instruction: ☒ CDP learning environments ☑**DGBL environment (Timez Attack)** **3) Mathematics teaching and learning content:** ☑ **Automatising multiplication/division** ☒ Automatising addition/subtraction ☑ **Other: conceptual understanding**
Do the current research findings support or contradict the abovementioned literature findings?				**☒ Contradicts**

Discussion: Although, once again, the current study did not measure performance and did not regard Timez Attack as an intervention, the findings thereof are in stark contrast with that of Jones (2011). The researcher is of the opinion that a sober analysis of the game design elements of Timez Attack, would produce insight into the game's immense potential to ensure conceptual understanding together with the gains in fluency. What was then overlooked in Jones's (2011) study – what caused the lack of conceptual understanding? The current study could conclude that even the best designed game, could fail in terms of gameflow, should it not be matched to the learner's individual interests and personality. Although the current study only examined the anxiety experiences of four participants, at least three of the learners' gameplay were derailed by anxiety created by the game context. To these participants, Timez Attack functioned as a CDP game: drilling in order to recall from rote memory. These participants were so anxious during the game that the more 'relaxed' gaming events – designed to produce conceptual understanding were possibly not attended to properly. The researcher could infer that these gaming moments were used to emotionally recompose themselves before they had to face the troll (testing game events) who were to hit them over the head should they persistently provide wrong answers.

Regarding 'so-called' motivational gains: The researcher strongly refutes the methodology whereby teacher's perceptions about learners' motivational gains are surveyed and analysed to produce findings on learner's motivational gains by playing Timez Attack. To survey learners themselves was probably not possible due to the developmental stage (8-9 years), but as literature (Eden at al., 2013) has been urging researchers to apply qualitative studies, or at least mixed-method approaches to effectively examine affect constructs like motivation as to eliminate dubious findings on affect by means of only analysing quantitative data. The following table (Table 8.1f) summarises the findings of three studies on the effect of CDP games on attaining automaticity in multiplication facts (Williams, 2000 and Wittman et al., 1998; Wong & Evans, 2007).

Table 8.1f. *Current body of knowledge: Correlations and contradictions (Williams, 2000; Wittman et al., 1998; Wong & Evans, 2007)*

Author(s) & Publication date	**Problem statement/ Research Problem**	**Research design**	**Major finding(s)**	**Overlapping constructs**
Research sub-question addressed: RSQ 4: How do Grade 4 learners experience anxiety in conventional classroom and home teaching environments during the automatisation of multiplication facts? RSQ 6: How do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts?				
8.1f **Wong and Evans (2007);**	To determine whether or not a multiplication program (based on systematic practice) would increase the recall of multiplication facts	Quantitative: Quasi experimental, pre-test/post-test design. Two groups (n=37; n=27) of which interventions differed (paper and pencil exercises or CDP gameplay). Average age of respondents: 10 years	Learners who used computers as part of their daily teaching generally learn more in less time. They also retain the information for longer.	**1) Affect in Mathematics education:** ☑**anxiety** (only Wittman, et al., 1998) ☒ other affect construct(s)
Williams, (2000) **Wittman et al. (1998)**	The effect of CDP software on multiplication Skills using 'Multiplication Puzzles' (paper and pencil exercise) versus 'Mad Minute' (CDP)	Action research project (single grade 7 class; 12 year old learners; pre-test/post-test design)	Use CDP games improves fluency in multiplication facts as it hold learners' interest and ensure enjoyment.	**2)Computer-assisted** instruction: ☑**CDP learning environments** ☒DGBL environment
	The relationship between automatisation of multiplication facts and elementary school learners' Mathematics anxiety.	Quantitative experiment Pre-test/post-test design with intervention. Two groups; high-anxious and low-anxious learners who received the same intervention (CDP gameplay). Average age of respondents: 10 years	CDP games could provide a learning environment that effectively reduces some students' level of anxiety when learning multiplication facts. High-anxious female respondents' anxiety levels significantly decreased by automatising multiplication facts through CDP gameplay.	**3) Mathematics teaching and learning content:** ☑ **Automatising multiplication/division** ☒ Automatising addition/subtraction ☒ Other:
Do the current research findings support or contradict the abovementioned literature findings?				**☒ Contradicts**

Discussion: Researchers have long assumed that CAI games do have added benefits in terms of automatisation of multiplication facts over pen/pencil and paper drills without making a clear distinction between CDP games and DGBL games. As DGBL games only developed and gained popularity at the turn of the century, the findings of Wittman (1998) and Williams (2000) could be regarded as valid, at the point in time. It was only when CDP games' so-called benefits could be compared with that of DGBL games, that the possible harming effects of CDP games came to light (Ghada, 2005; Leh and Jitendra, 2013). As far as the researcher could ascertain, it was only through the preliminary research findings of Boaler (2015) that research attention was focussed on the possibility that rote memorisation of multiplication facts by means of CDP gameplay could induce anxiety. The current qualitative study's research findings could draw more attention to this preliminary statement. Although the findings cannot be generalised outside the research context and game context (Smartygames) of the current study, the intensity of the anxiety experiences observed and recorded in a CDP environment as opposed to the anxiety experiences observed and recorded in two different DGBL environments, could alert researchers to also turn face towards the possible harmful effects of the use of CDP games in attaining automaticity in multiplication facts. Answering to the research questions will elucidate the aforementioned statement.

8.4 Answering the Research Question

Answering to the main research question entailed in-depth analysis of the data collected in the second research phase to answer to research sub-questions 4, 5 and 6 (research sub-question 1 and sub-questions 2 and 3 were answered in the process of developing the research instruments to be used as research tools during the all-important second research phase).

8.4.1 Answering to the research sub-questions

8.4.1.1 Research sub-question 4

To understand to what extent, if any, do Grade 4 learners experience anxiety in conventional classroom and home teaching environments during the automatisation of multiplication facts?
The aim of answering this sub-question was to obtain information about the participants' anxiety experiences associated with previous teaching and learning of multiplication facts, the social environment in which these skills were acquired, participants' mathematics self-concept at a given point in time, and participants' attitudes and belief regarding mathematics. The researcher had to be aware of possible anxiety and the extent of the participants' anxieties (if any) when entering the unfamiliar CAI environments during the gameplay sessions that followed. Briefly stated, the findings were:

The observed *anxiety↔confidence* experiences were well-represented and balanced in terms of frequency (Chapter 7, sub-section 7.3.1.1 and Figure 7.7a and Figure 7.7b). When the attributes of these experienced academic emotions were examined, it was revealed that more *anxiety* than *confidence* experiences were chronic (trait position). The observed anxiety and confidence experiences in the state position (once-off, momentarily experiences) correlated (Chapter 7, sub-section 7.3.1.3). The construction domains (from which beliefs and attitudes regarding mathematics, teaching and learning of Mathematics and participants' mathematics self-concept originated) of observed anxiety experiences were partially self-constructed and partially socially constructed (Chapter 7, sub-section 7.3.1.2). From the explicit verbal accounts provided by all four participants on the different social settings, from which their own Mathematics self-concepts could have partially stemmed, the following outcomes of the observed negative affect were derived:

- Confidence regarding other subjects (languages were singled out) was not transferred to Mathematics. Even within Mathematics, confidence in one content area and topic (for example automatisation of addition and subtraction facts) was not transferred to other topics (for example multiplication) in the same content area and…
- an overall positive self-esteem does not guarantee a positive Mathematics self-concept, but it could be inferred that a poor Mathematics self-concept could, over time, culminate into a poor overall self-esteem (Chapter 7, sub-section 7.3.1.4: Reflections on mathematics and mathematical self-concept)

The *social construct domain* in which mathematics beliefs and attitudes originated, can (according to the focus group interview data analysed as discussed in Chapter 7, sub-section 7.3.1.4) be narrowed down to a)demonstrating acquired mathematic skills in front of peers, b)the support from parents in automatisation of multiplication skills and c)the teaching characteristics of the mathematics teacher. It appears as though the fear of being humiliated in front of peers, by providing incorrect answers, and the exposure to parents' time-drilled and rote learning (endless repetition by writing out times tables' facts) support measures, created the most anxiety experiences. Two participants' perceptions of their Mathematics teacher, as strict and unapproachable, also led to anxiety experiences [par. 55] [par.56]. These findings are congruent to that of Jordan (2007) and Berch and Mazzocco (2007) who argue that there are many learners with an inborn aptitude and intuitive knowledge to working with numbers; these skills can however only surface whenever in a conducive social environment.

The *teaching and learning domain* can be narrowed down in a similar manner (Chapter 7, sub-section 7.3.1.2): Participants displayed an aversion to rote memorisation could have been present, especially when the rote memorisation was coupled with time-drilled practices (as in weekly mental mathematics assessments). Having to deal and resolve feelings of anxiety rationally (attempting to calm themselves down), while simultaneously having to process information on a cognitive level to derive assessment outcomes, seemed to have resulted in cognitive overload, impairing the functions of their working memory. They were therefore unable to retrieve what they studied and knew the previous day from their long term memory in an efficient manner. This finding is in line with the research findings of both Ramirez et al.'s (2013) and that of Artemenko, Daroczy and Nuerk (2015).

In contrast, *confidence* experiences were observed to only be self-constructed; and mostly found in the state position, implying that the participants indicated that they were only confident in Mathematics in some, but not all domains. In this regard, the following coping skills in attempt to alleviate their own feelings of anxiety were mentioned:

- One participant revealed that *'safety is in numbers'* – referring to surrounding themselves with peers and not with numbers (digits): They deliberately surrounded themselves with peers in classroom situations, this prevented them being singled out by the teacher and expected to answer to questions in front of peers. During an informal conversation with this participant (outside the interview situation), the researcher requested clarity on her interview remark as paraphrased above [par.55, 62]. She explained that when she sat in between the clever children in her class, the teacher seldom noticed that she did not raise her hand when questions were asked [par. 58].

- When questioned in the home environment, one participant resorted to biding for time when having to answer times table questions –allowing for more cognitive processing [par.41].
- Enhancing their own self-confidence: In the interview situation two of the participants confidently declared how they have already automatized all their times tables. One of the participants stated that she was fluent from Grade R [par. 31]. These participants' school records (weekly mental mathematics tests), as well as their performance in the gameplay sessions, revealed a situation that could be interpreted very differently, as the ones they were attempting to depict during the interview.
- Participant D resorted to another coping strategy by blame shifting and implicating the mathematics teacher, stating that "*As a maths teacher you have to explain to a child that does not know, because otherwise you're not actually teaching maths. Because then they going to fail the test. Then you can go back and say to the teacher that it is her fault, because she didn't explain to you*." *[par.56]*

No *anxiety↔confidence* (or other co-existing academic emotion) experiences were attributed to positive or negative beliefs, and attitudes towards mathematics (the abstract science of number, quantity, and space). Due to abovementioned findings, it is clear that anxiety experiences could have clouded participants' outcome focus. However, in contrast to Pekrun et al.'s (2011) research findings, these anxiety experiences together with the negative academic emotions (boredom, shame, hopelessness and anger), did not, at a given point in time, influence participants' outcome focus. Focus was still found to be *on the task and hand* and has not (? yet) led to focus on *task avoidance*. In the absence of anxiety experiences, the focus should however have been on achievement outcomes (Pekrun et al., 2011).

8.4.1.2 Research sub-question 5

To what extent, if any, do Grade 4 learners experience anxiety in CDP learning environments during the automatisation of multiplication facts? The following summative findings were derived from analysing both verbal (individual interview data) and non-verbal (gameplay recordings) data sets:

The observed non-verbal manifestations of anxiety were approximately 70 times that of confidence. This trend was confirmed by the verbal expressions of experiences that could be interpreted as anxiety experiences. Although only a single (and probably misinterpreted – Chapter 7 sub-section 7.3.3.1) manifestation of confidence was observed, it could not be confirmed through analysis of verbal data. Participant C did however express confidence – not in her own abilities while playing the game – but in the CPD game as an assessment tool (Chapter 7, sub-section 7.3.3.1). According to the researcher's observations of the non-verbal data, a single experience of pride and four experiences of enjoyment were manifested. When compared to manifestations of anxiety, the data was not substantial enough to derive any findings. Co-existing negative academic emotions were, however, found to be more substantial: shame, boredom and hopelessness were expressed non-verbally more than verbally. Only hopelessness was inferred during analysis of verbal data. Participants unanimously stated in no uncertain terms the CDP game was the least enjoyable game of the three games played. By not succeeding in the game and learning goal, they felt hopeless (Chapter 7, sub-section 7.3.2).

Observed feelings of anxiety were portrayed by an array of body language expressions. These observations confirm the findings of Navarro and Karlins (2008) who found that the *physiological* and *motivational* components of anxiety are conveyed through human facial expressions, gestures, body movements, postures and vocal interjections. Analysis the verbal data could reasonably confirm the latter findings. All participants expressed feelings of anxiety during the game and they attributed these feelings to a) the complicated interface and game controls design as well as the timer displayed too prominently resulting in them experiencing a loss of control in and over the game; b) the perception that they will never become immersed in the game; c) the imbalance between the level of the learning goal and participant's level of automatisation of multiplication facts at a given point in time; and d) the inability of the CDP game to provide players with informative and corrective feedback. The only feedback provided was by removing incorrect answers by returning them to the heap of possible answers (Refer to Appendix E for a description of the game).

8.4.1.3 Research sub-question 6

To what extent, if any do Grade 4 learners experience anxiety in DGBL environments during the automatisation of multiplication facts? The following summative findings were derived from analysing both verbal (interview data) and non-verbal (gameplay recordings) data sets. Due to the different gaming environments of the two games, the findings derived were also distinctively different.

Anxiety experiences: The number of observed manifestations of anxiety experiences in both TA and Am (as revealed through analysis of the non-verbal data) correlated, but were only approximately one quarter of that of the CDP game (Chapter 7 sub-section 7.3.4.1). The findings regarding the two DGBL games were, however, in contrast to the findings revealed by the verbal data: TA pointed more and more severe feelings of anxiety than MA. It was only Participant D who admitted to being 'stressed' while playing Am, but it could be confirmed that these anxiety experiences stemmed from extraneous factors outside the game context and could not account for all the non-verbal anxiety manifestations revealed by all participants. (Refer to sub-section 7.3.2.2). Although one of the participants stated that they also experienced anxiety while playing Am, the researcher was confronted with whether or not participants' body language (facial expressions, gestures, a posture and a vocal interjection) did perhaps communicate the anxiety experiences that the participants' were not prepared to admit to - verbally and rationally? Furthermore the observed non-verbal manifestations of co-existing negative academic emotions of *shame*, *hopelessness* and even three manifestations of *boredom* and a single one of *anger*, were significantly more than similar emotions observed during TA gameplay. Only a few manifestations of *hopelessness* were observed. The discrepant findings outlined above will be further explored in the following paragraphs when confidence experiences in the two DGBL environments are contrasted. The participants' attributions for their anxiety experiences while playing TA will now be outlined:

- Participants A, B and C regarded the learning goal in TA as difficult and expressed that they were not fluent enough to be confronted with mixed multiplication facts at the point in time and still preferred a single multiplication table at a time. Reality, however spells out that TA, by doing a baseline assessment during the introduction part of the game, accommodates a player at his/her own competency level and also introduces one times table at a time while, simultaneously, revising those already reinforced. The difference between the strategies of the two games, is that Am allows the player to choose the times table, whereas, in TA, the game decides. Another distinguishing factor is TA's incorporation of inverse operations (for example 2 x 6 and 6 x 2) when introducing a new times table. It can therefore be understood why participants incorrectly commented that TA provides mixed problem types.
- The game context of TA was unanimously attributed as the main anxiety inducing game element: Analysis of all participants' detailed comments led to the abovementioned findings. The following game elements was mentioned: Three participants deplored the game's visual sensory stimuli overload. The gaming environment of dungeons, a dragon's cave with a troll and Shrek-like avatar was not experienced as pleasantly challenging and no fun-filled moments were revealed. Both the abovementioned elements were set as pre-requisites for conducive CAI environments by Habgood and Ainsworth (2005), Dondlinger (2007) and Ke (2008). Another participant was taken aback by the mood of the game. According to her, it was not only created by the visual sensory stimuli, but also by the auditory input – the load pulsing music (Participant C, lines 53, 54). To these four participants, the TA game context was a distractor and they admitted to struggling to concentrate in pursuing the learning goal. According to the verbal data, TA therefore did not raise the participants' individual interest in pursuing the game goal. Malone (1981), Lepper and Cordova (1992) as well as Garris et al*.* (2002) explain that this lack of interest would derail the learning goal, something they coined as 'cognitive curiosity', would have followed.
- Apart from *anxiety*, the co-existing, negative academic emotion of hopelessness was observed in the analysis of three of the participants TA gameplay (non-verbal) data. Analysis of the verbal data revealed experiences of *shame* as well. The researcher therefore inferred that the expressed anxiety experiences could not have been attributed to positive stress or excitement.

Confidence experiences: Analysis findings of verbal as well as non-verbal data sets converged and it can be argued that Am was played with an overall feeling of confidence by all the players, although participants experienced some feelings of anxiety as already stated. The researcher is inclined to interpret and attribute the anxieties during Am gameplay to intrinsic factors on the part of the participants. As confidence levels (observed through tallied manifestations of non-verbal communication) were twice as high as that of TA, participants seemed to pursue the game and learning goal with confidence and could easily have over-estimated their own abilities to attain the learning goal. When discovering that they were failing at the learning goal, they were dragged into a downward spiral of emotions, commencing with *anxiety, shame, hopelessness* and *anger* (Chapter 7 sub-section 7.3.4.2). The confidence experience expressed with regards to TA can be stated as follows (followed by the confidence attributes experience in Am):

- Participant D was the only participant that expressed confidence while playing TA. Her comments were, once more, different to that of the other participants. She remarked that exposing players to problems that they are uncomfortable with, may raise the game's expectations of the player and it could motivate the player. She therefore, instinctively and unknowingly pointed out TA's ability of keeping a player in the Zone of Proximal Development (Vygotsky, 1978) – a pedagogical strategy that CAI researchers, Engeström (2000), Roth (2002), Gee (2007) and Felicia (2009) also stressed as an important game design criteria. Where the other participants experienced the repetition of questions and reinforcement (handled by the troll game character) to be stressors, Participant D commended repetitive exercises as a good teaching and learning strategy as it fostered feedback strategies of reflection, transfer and eventually automaticity (Chapter 3, sub-section 3.2.7).
- Analysis of verbal and non-verbal data converged when participants' confidence experience were analysed. The following attribution could however be singled out; the game context was found to be appealing, with respect to both auditory and visually stimuli and the plot (storyline) appealing. All participants commended the 'cute and friendly' mouse-like avatar with his over-sized round head. Although the game was designed before the research findings of Magner et al. (2014) regarding the emotional design relationship between warm, bright interface colours, round face-like shaped avatars and motivation to pursue a game's learning and game goal, Am seems to have already demonstrated the results.
- Am was furthermore observed to be interactive and was experienced as individualised and differentiated in terms of learning expectations (goals). Participants did not feel over-challenged and commended the fact that they felt confident because they were successful during the early rounds. They were therefore able to attend to the game and learning goal with confidence. This confidence was not transferred to the later round(s), resulting in what with seemed like negative effect as already explained.
- *Gameflow:* As *enjoyment* in a game is viewed as a pre-requisite for immersion, and immersion as a sign of *confidence* and not *anxiety*, the question of whether both DGBL environments could result in participants becoming immersed. Sweetser and Wyeth (2005, p.10) refute anxiety experience when players become immersed by stating that an immersed player enters a stress-free environment with "deep but effortless involvement, which can often result in loss of concern for self, everyday life and an altered sense of time." With the all the participants unanimously declaring that they were immersed in Am, none of them could say the same regarding TA. This finding, however, holds no ground as immersion is a highly individualised experience and the research findings examined by the researcher repeatedly pointed to individual difference and especially to the gender difference in potential immersion in games (Casell & Jenkins, 1998; Hartmann & Klimmt, 2006; Roig & Hurtado, 2004).

8.4.2 Answering to the main research question

The abovementioned findings, although subjectively derived from all the different data sources analysed, converged and *pointed to the examined CDP learning environment being more at risk with regards to inducing or aggravating existing anxiety experiences (relating to automatisation of* *multiplication facts) than the DGBL environments examined*. Although the CDP and DGBL games were elected as research tools by means of research findings of the current study (set out in Chapters 3 and 6), the abovementioned finding is, however, only confined to the gaming environments of the three games. It cannot be generalised to the context of other CDP and DGBL games, nor can the findings be generalised to any other gaming experiences with players other than the research participants at the given point in time of the recorded gameplay sessions.

The significantly discrepant research findings about learners' anxiety experiences in the two different games genres, contributed to the following conclusions:

The Grade 4 leaner participants experienced more anxiety during automatisation of multiplication facts in the CDP environment than in the two different DGBL environments. When participants' verbal accounts of anxiety experiences in the conventional learning environments where compared to verbal accounts of the anxiety experiences in CDP environments, it could be concluded that the CDP environment was entered with a predisposition: chronic anxiety regarding automatisation of multiplication facts that stemmed from the rote memorisation of the facts in class as well as at home.

No indication of demonstrating conceptual understanding as pre-requisite to rote memorisation was mentioned with respect to both class and home. The CDP learning environment was entered with initial confidence due to the CAI impression thereof, but the moment mistakes were made and no corrective feedback was provided, high levels of anxiety became evident. The count-down timer became an additional stressor and the learning goal could not be achieved at all.

As time-drilled practice with no corrective feedback is a common characteristic of all CDP games, it can be inferred that the participants probably would have demonstrated similar anxieties in all other CDP environments. The lack of corrective feedback that can enhance (or create) conceptual understanding of multiplication facts is implicated as the primary stressor in CDP games. Due to inadequate understanding, rote memorisation is inevitable. The difficult process of recalling the facts that were ineffectively stored in participants' long term memory, is further derailed by interface design's countdown-timers, often displayed too prominently. This aspect accounts for the second stressor. A third and final stressor lies in the fact that although CDP software are labelled as "games", no clear distinction between the game and learning goals are made. The *learning goal* inevitably *becomes* the *game goal*. From a child's perspective, however, playing (and not learning) culminates in winning. As CDP games demands 100 percent performance (automaticity) before being declared competent within the game, players seldom exit the game as winners and (as in the case of the research participants) may become despondent; never to return to the game.

DGBL games are usually considered to be CAI's 'saving grace' when let down by CDP games. Many a research study (see sub-section 8.3 for examples of 'Timez Attack' and 'FASST Math') singles out a DGBL game used to automatize multiplication facts and use it as the only research tool or intervention in experimental studies. Together with the (mostly quantitatively derived) positive research findings in terms of the learning goal (performance), the praises of a specific game are then sublimely sung. The current study, conducted from an interpretivist perspective, did however reveal findings that could caution against a possible one-sided approach of assuming that a one-size-fits-all type of DGBL multiplication game do exist.

The current study made use of two DGBL games with contrasting game contexts, support measures, learning strategies, plots, avatars, characters and game goals, but still pursuing the same learning goal – automatisation of multiplication facts as per Grade 4 specifications for mental mathematics. Despite all these differences, both games complied *fully* with all design criteria researched in Chapter 3 that sufficed as criteria for effective CAI games. As a result, both these games led to significant reduction of anxiety experiences (verbally and non-verbally expressed) when compared to the recalled anxiety experiences while playing the CDP game. When the *anxiety↔confidence valence* was however examined, it came about how and why the sampled participants for this study experienced the two games differently.

Although the verbal and non-verbal data analysis of both games converged into similar findings regarding anxiety experiences, Am instilled significantly more feelings of confidence than TA. Participants attributed the heightened confidence to the sensory pleasing game context of Am. The context of TA did however not please the senses of the respondents: the verbal as well as non-verbal analysis findings pointed to experiences that ranged from 'disturbing' to 'appalling' that interrupted gameflow and derailed pursuing both game and learning goal. When Am gameplay was examined even closer, it then came about that the many short-lived manifestations of anxiety during Am gameplay was actually caused when players (in a state of gameflow and total immersion) found themselves to be repeating a level due to careless mistakes made.

Despite the undisputed upper hand of DGBL environments over and above CDP games in terms of the potential to induce anxieties, two important preliminary conclusions regarding anxiety experiences in DGBL environments emerged. Firstly, DGBL environments – especially in terms of the game contexts - need to be closely matched with the specific interests and personality traits of individual players at the developmental age that the game was designed for. It could be that the match between players' interest/personal preferences and game context could be more significant than the match between player skill level and in-game learning challenge when optimum gameflow is envisaged. Secondly, although a specific game may display a strong design, the game context and not necessarily the mathematical challenges could actually instil fear in players. These fears may then be interpreted as Mathematics anxieties as the player associates the subsequent struggles to master the game goal with the learning content of the game. In situations like these players tend to implicate the learning content of the game when stating that the game is too difficult. For example: although the learning content of Am replicated that of TA, players experienced TA as difficult due to the negative in-game affective experiences caused by the game context that did not suit the participants' interests and personal preferences. These conclusions need to be viewed as preliminary as the findings cannot be generalised to other populations. More research with larger samples could verify or refute abovementioned findings.

8.5 General Challenges

Apart from the specific design-related challenges of this study, as already outlined in Chapter 4 (sub-section 4.12) and Chapter 5 (sub-section 5.10) and further discussed in various sub-sections of Chapters 6 and 7, the following general challenges to qualitative studies encountered in the current study, will be briefly explained.

Creswell (2007) cautions about the undisputable biased role of the researcher by stating that since the researcher constantly interpreted what she saw, heard and understood, the findings and conclusions could not be completely separated from her own background, prior experiences and her own teaching context. The researcher firmly believes that all people have biases, whether or not they are aware of their biases. By continuously being mindful of researcher biasness, the researcher attempted to minimise the challenges that researcher bias could cause in the study by consciously guarding against confirmation bias that may have occurred. The researcher therefore constantly discarded her own pre-conceived thoughts about how the study could unfold as she feared utilising the respondents' experiences and recalled experiences to confirm her own pre-conceived ideas. In the end, the researcher was, in fact, pleasantly surprised with the outcomes of the study.

The large amount of data generated during the focus group interview was however a design limitation, but also unavoidable and unusual to the approach. The researcher had little control over the fact that the participants frequently went off-topic. Applying a more stern approach would have kept the participants to the topic, but would have inhibited the participants' spirit as well, thus endangering the depth of the revelations about anxiety experiences when automatising multiplication facts in class and at home. It stands to ground that amidst all the interpretations of the participants, that of the researcher and of the reader(s) of the dissertation, multiple interpretations of a single reality (Grade 4 learners automatising multiplication facts by means of CDP and DGBL games in a suburban ordinary primary school) emerged. Therefore refuting *naïve realism* - the belief that a single, unambiguous social reality exists which is entirely independent of the researcher and of the research process (Mays & Pope, 2000). Before concluding the chapter by stating some of the researcher's reflections on the study, recommendations for future research and teaching and learning strategies concerning automatisation of multiplication skills will be outlined.

8.6 Recommendations

8.6.1 Recommendations for future research

The researcher is confident that this research produced meaningful qualitative evidence which has relevance for a wider application beyond the specific sample involved in the research. Sioni and Chittaro (2015) speculate that visually-based human-computer interface (a sub-division of human-computer interaction (HCI) research) attracts the attention of many a researcher in the fields of both neurology and technology, *electromyography* (EMG*)* especially can also be used in education research to study Mathematics anxiety experiences in different CAI environments with more rigor and with larger samples.

Another recommendation for further research involves an investigation into the causal effect of rote memorisation of number facts without sufficient prior conceptual understanding on the onset of Mathematics anxiety in learners between the ages of 6 and 9. To improve the validity of the findings, longitudinal studies implementing mixed methods research designs, are suggested.

A final recommendation: A distinct pattern between the prevalence of anxiety experiences, followed by shame and hopelessness in close proximity, was found by accessing the single case study (see Chapter 7, sub-section 7.3.1.1). Further investigation into this observed phenomenon could be worthwhile as it could possibly lead to a better distinction between positive anxiety experiences (positive stress or excitability) and negative anxiety.

8.6.2 Recommendations for district officials monitoring implementation of Mathematics curriculum and supporting policies.

Although '*mental mathematics'* is a curriculum directive as from Grade 1, rote memorisation and speed/timed drills are not specified, nor prescribed (DoBE, 2011b). As a matter of fact, mental mathematics prior to conceptual understanding is discouraged; "When doing mental mathematics, the teacher should never force learners to do mental calculations that they cannot handle - writing materials and/or counters should always be available for those learners who may need them." (DoBE, 2011b. p.13). Reality tends to paint a different picture of number facts being "recited" and/or drilled by means of timed-drill pen and paper exercises. In these instances, curriculum directives are negated and will continue to be negated unless teaching practices are better monitored by curriculum facilitators capable of guiding teachers into promoting automaticity through play (pen-and paper or differentiated DGBL environments).

8.6.3 Recommendations for teachers and parents

Since technology is now an integral part of not only adult life, but also that of learners from the earliest of grades (and ages), the multitude of CAI games and applications available to automatize number facts can no longer be overlooked by schools. We need to realise that the effort and money afforded to the design of good DGBL game applications outsmarts most of the teacher's class efforts to teach and reinforce number facts. The teacher's materials cannot compete with the interactive and appealing gaming contexts used by games to automatize number facts. As the learners concentrate on the game goal so intensely, the learning goal is attained almost sub-consciously without rote memorisation and time-drilled exercises; simultaneously promoting conceptual understanding. Even if the recommended strategies are not feasible in class due to monetary constraints, foundation school phase (Grades R to 3) teachers should invest in providing the learners with 'gameplay' homework exercises, as a choice over and above more of the work that was already completed in class.

Households and smartphones and/or tablets or other handheld electronic devices are synonymous. Parents are urged to investigate the myriad of applications available on Google Play Store and Apple-I-store. Should a parent know their child well enough, as both person and learner, they would be able to download appropriate apps for automatising number facts. As children take to gameplay like fish to water, parents could play an invaluable role in incidental automatisation of number facts (a skill required for the rest of the child's life), therefore eliminating the detrimental effect of rote memorisation that frequently dominates teaching and learning of number facts in the foundation school phase. The researcher, being in the fortunate position to be the author of a weekly parent information blog, would certainly grasp the opportunity to use the blog as a forum whereby the research findings can be cascaded to parents of primary school learners.

8.7 Personal reflections

The "itch" as described in the acknowledgement section of this dissertation, originated almost 40 years ago when the researcher (as a novice teacher) realised that even with conceptual understanding displayed in the classroom, the more eager parents' children who were drilled through repetitive practice and rote memorisation often fared worse in mental Mathematics (involving multiplication facts) than learners who admitted to not having studied at home. The latter group relied only on the conceptual understanding that was formed in the classroom. The first group became more and more despondent and feelings of anxiousness accompanied by what could have been described as psychosomatic aches and pains before, during and after assessments. The "itch" or concern escalated when the researcher's twin daughters (with significantly different learning modalities) had to automatize multiplication facts approximately ten years later. The researcher (as mother) was delighted with the CDP games that arrived on the market and so was twin A. Twin B became anxious, despondent and rejected the available CAI games altogether. It was only years later that she joined her sister in playing Mathematics games, when DGBL games became available and empowered her with conceptual understanding of algebraic terms – in a way that neither her Mathematics teacher, nor the researcher could succeed by using pen and paper teaching strategies.

Needless to say, the 'concern' evolved into a deep-rooted desire to investigate the different methods in which learners react when automatising multiplication facts in the different learning environments. Did the study shed light on the authentic barriers to learning Mathematics that the researcher faces in her everyday line of duty as a learning support coordinator? Undoubtedly! This relentless, yet fulfilling journey of writing this dissertation, focussed the researcher's perspective regarding affective experiences regarding Mathematics (amongst others) in the following ways:

- Knowledge, fundamentally grounded in theory, deepens understanding of Mathematics anxiety not only as a multidimensional construct, but especially as a construct that could be more learner and environment specific than what the researcher could ever realise. Therefore, no intervention, whether conventional or CAI-directed, may ever follow a one-size-fits-all approach.
- The selection of appropriate interventions should first and foremost necessitate understanding the learner, not only as a learner, but more importantly as a person as well. Only with a sound knowledge and understanding of the learner in need, his/her interests and character traits, can interventions be narrowed down until a point is reached where a few viable interventions can be suggested and the learner is allowed to choose the most desirable or attractive intervention.
- The use of CDP games that (due to easy accessibility and relative low cost implications) tends to dominate the CAI Mathematics gaming environment available in school, should receive some serious consideration as it could be the root of many an evil in causing Mathematics anxiety.
- Parents need to be educated regarding the use of Mathematics games and especially the multitude of Apple and Android apps available at the push of a button, as random download and play games could do more harm than good regarding the affective experiences of players. The in-depth investigation into the design features of CAI-gaming software, provided the knowledge and understanding to (together with teaching and learning support experience) guide parents in supporting their children's Mathematical development by choosing the most appropriate software that matches their child's unique learning ability and personal attributes.
- The ACAT theory (Chapter 2, sub-section 2.3.2) considers computers (or handheld devices) as digital artefacts that should be programmed in such a way that the manners in which learners manipulate the artefact are conducive to generating Mathematical meaning and understanding

(Vandebrouck et al., 2013). This theory should carry more emphasis in the initial training and continuous professional development of Mathematics teachers as it emphasises the vital role of the teacher (representing the social group) in orchestrating the interaction between the learner (subject) and the object (Mathematics learning content). An orchestra (class) can certainly not perform an admirable symphony (constructing Mathematical knowledge and understanding) without a conductor! In schools' CAI realities, the conductors however often leaves the orchestra to play on its own.

On an even more personal level, the researcher can identify with both avatars of the DGBL games that were applied as research instruments: During the initial stages of the research journey the researcher was as excited as the bright-eyed and bushy-tailed friendly mouse avatar of Arithmemouse. Gameplay was real easy and the game did not challenge the researcher's skills much. Soon after the extensive literature studies as presented in Chapters 1 and 3, the game plan changed. All of a sudden the researcher found herself in the dark dungeons of Timez Attack where the alien-like avatar rushed to and fro in the quest of finding answers to what seemed as an insurmountable challenge at the point in time. The quest to find a desirable and mutually acceptable way out of the dungeons became an endurance race. Inevitable confrontations with the scary, ugly troll who forced the avatar to learn by means of harsh reprimanding (hitting avatar over the head with a baton) followed. But alas, no turning back or secret escape routes were available. After what felt like eternity, the checkpoint was in sight. Where the researcher has now reached this check point, the game context and 'feel' of the game have not changed; what has changed, is the automaticity level of the researcher: All the multiplication facts have not been automatized yet, but deep learning with conceptual understanding surfaced. Whether the researcher will attempt to 'automatize the remaining multiplication facts' is a probability, but not a given as it seems that mental Mathematics in some of Asian countries are extending the challenges to 19x19 instead of the traditional 12x12.

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Appendices

Appendix A

Facial expressions, gestures, body movements, postures and vocal interjections associated with academic emotions (A to I in the first column)

(Source: compiled from Darwin, 1965; Wallbott, 1998; Givens, 2002; Picard & Daily, 2005; D'Mello & Graesser, 2007; Fairclough, 2008; Navarro, & Karlins, 2008; Pease & Pease, 2008; Arroyo et al., 2009; Ahn et al., 2010; Ekman et al., 2013)

ACADEMIC EMOTIONS	FACIAL EXPRESSION				POSTURE (specific reference to seated posture as in CAI environments)	GESTURE	BODY MOVEMENT (specific reference to seated postures as in CAI environments)	VOCAL INTERJECTION
	FACIAL MUSCLE CONTRAC-TION	EYE MOVEMENT & BLINKING	PUPILLARY RESPONSE	HEAD MOVEMENT				
A. CONFIDENCE	☛ *dilating* eye, nose, throat, and mouth openings ☛ one or both eyebrows raised with… ☛ friendly smile or laugh	☛ Maintaining eye contact; (not staring though) ☛ comfortable usual blinking ☛ Looking up and to their left: successfully retrieving from memory	☛ Dilated pupils	☛ Head tilted slightly backward; keeping eyes to the front ☛ Face-to-face or levelled gaze	☛ Thumbs carried high in hand movement ☛ Hands on hips ☛ Body held erect, head upright (in an almost uncomfortable manner) ☛ Arms crossed in front of chest	☛ Complete shoulder shrug that accompanies answer/ response ☛ Palm-down: A gesture in which the hand(s) and forearms assume the position used in a *floor push up*. ☛ Steeple: A position in which the *tactile pads* of the fingertips of one hand gently touch their counterpart on the other hand	☛ Arms spread out wide at torso height ☛ Limited, smooth body movements	☛ **'mwah-hah-hah'** (confident laugh) ☛

ACADEMIC EMOTIONS	FACIAL EXPRESSION FACIAL MUSCLE CONTRAC-TION	EYE MOVEMENT & BLINKING	PUPILLARY RESPONSE	HEAD MOVEMENT	POSTURE (specific reference to seated posture as in CAI environments)	GESTURE	BODY MOVEMENT (specific reference to seated postures as in CAI environments)	VOCAL INTERJECTION
B. ANXIETY	• Pulling brows together, may be accompanied by pouting and… • Slightly raised eyebrows (uncertainty; anticipating anxiety) • Widening of mouth/narrowing lips by pulling at one or both corners • Opening mouth to only reveal bottom teeth • Biting at lower lip • Raised upper eyelids; tense lower eyelid • Extreme anxiety: face crunches up; eye slant follows frown and brows pulled together leaving eyes almost closed	• Real wide eyes or extreme narrowing of eyes • Blocking or partial blocking of eye(s) • Squinting • Sideways glance • Rapid blinking • Darting eyes • Tears likely	• Constricted pupils	• Shoulders pulled up • Visible/audible swallowing (closing of mouth) • Jerking head movement • Face turning pale (blanching) • Lowered chin • perspiration	• Arms thrown wildly over head • Arms protruded: as if pushing away from chest with hands turned upward, palms facing away from body • Arms pressed closely against sides or chest	• Hand wringing or fingers interlaced • Quivering hands • Twitching wrist, hand and finger movement • Lip licking in attempt to relief anxiety • Biting nails • Putting finger(s) into mouth or to lips in attempt to relief anxiety • Covering mouth and/or nose with hand • Touching tip of nose • Yawning may indicate uncertainty and anticipated anxiety • Self-touching and even scratching	• Low activity with intermittent jerky movements • Turning torso away • Arms and elbows drawn tightly towards body • Hands/arms deliberately withdrawn	• Throat clearing • **'Eek'** indicates an unpleasant surprise that could be experienced as fearful • **'Huh'**-confusion and uncertainty with or without anticipated anxiety • **'Oh-oh':** anticipating negative repercussions and anxiety as result thereof • **'Yikes':** fear or deep concern

ACADEMIC EMOTIONS	FACIAL EXPRESSION				POSTURE (specific reference to seated posture as in CAI environments)	GESTURE	BODY MOVEMENT (specific reference to seated postures as in CAI environments)	VOCAL INTERJECTION
	FACIAL MUSCLE CON-TRACTION	EYE MOVEMENT & BLINKING	PUPILLARY RESPONSE	HEAD MOVEMENT				
C. RELIEF	• Eyes almost closed and crinkled as if to hide self-content • Smile or even laughter	• Tearful • Looking straight up	• dilated	• Tilt head as to be able to look straight up • Lowering chin on chest while crunching down	• Sitting up straight, lower back curved inward while inhaling	• Folding arms over abdomen • Rubbing palms together • Touching side of nose • Putting finger(s) on lip • Lip licking	• Crunching shoulders forward while folding arms across abdomen	• **'Phew' and 'Whoa'** communicates relief • Exhales with a **'Whoosh'**
D. HOPELESS-NESS	• Refrain from making eye contact • Poker face: blank expression	• Roving eyes: avoids focussing at specific object or point; slow drifting movements of the eyes from side to side	• dilated	• Swaying head movement (could complement roving eyes as well)	• Slouching	• Arms hanging loosely at side of the body	• Passive; slow sluggish movements; otherwise motionless	• Deep sighs
E. ENVIRON-MENT	• Smiling & laughing • open mouth lowering jaw (relaxing face muscles) • widening of eyes with raised brows	• Looking up and to their left= tapping into imagination • looking down and to their right= retrieving from sensory memory	• dilated	• Head nods to and fro	• Body held erect, head upright; • Clasping hands	• Clapping hands • Slapping hands onto flat surface-palms down • Arms energetically raised skyward • Full (complete) shoulder shrug	• Jumping; dancing; body thrown backwards • Body swaying from side to side	• Shoulder shrug often accompanied by often accompanied '**Aaaaah'** • **'Boo-ya'** as a cry of triumph • **'Ha'** expresses joy • "**Hurrah**" is an exclamation of triumph or joy. • '**Oooh!"** denotes pleasure • **'Rah**' signals triumph

ACADEMIC EMOTIONS	FACIAL EXPRESSION				POSTURE (specific reference to seated posture as in CAI environments)	GESTURE	BODY MOVEMENT (specific reference to seated postures as in CAI environments)	VOCAL INTERJECTION
	FACIAL MUSCLE CON-TRACTION	EYE MOVEMENT & BLINKING	PUPILLARY RESPONSE	HEAD MOVEMENT				
F. BOREDOM	lips pressed together nose pulled up accompanied by raised brows	Looking up and to their right: distracted- prefers own thoughts Gazed look; little and slow blinking Rolling of eyes	Constricted	Motionless; turning face away; Head tilted backward; eyes looking upward	Slouching; Leaning forward; resting head on hand Turning face away from computer screen	Passive Snapping fingers Fiddling with hands/fingers Often accompanied by audible sigh	Motionless; Deliberately turning body away Low movement activity Shifts in seat	**'blah'** **'Ho-hum'**
G. PRIDE	One or both brows raised; accompanied by subtle smile		dilated	Head tilted backward in tandem with raised brow(s)	Arms crossed in front of chest Hands exposed with thumb(s) turned upward Arms flung into the air while letting out a loud 'yes'	Punching upward with clenched fist Embracing or hugging others or the object of pride Arms waving high up in the air	Body erect	'**Yes'**
H. SHAME	Blushing Pouting: brief mouth shrug	Eyes casted downward; avoids eye contact Darting eyes	constricted	Turns face away Head hangs on contracted chest	Bent down in an awkward manner	Nervous hand and finger movements Covers (or partially covers) eyes by placing hand horizontally over brows	Turning entire body away	Soft "**Ugh'** Soft '**Uh-oh'**

ACADEMIC EMOTIONS	FACIAL EXPRESSION				POSTURE (specific reference to seated posture as in CAI environments)	GESTURE	BODY MOVEMENT (specific reference to seated postures as in CAI environments)	VOCAL INTERJECTION
	FACIAL MUSCLE CON-TRACTION	EYE MOVEMENT & BLINKING	PUPILLARY RESPONSE	HEAD MOVEMENT				
I. ANGER	• Clenched jaw • Gritting teeth • pressed lips • extreme frowning • flared nostrils • children may pull a 'crying face' • tightened face muscles	• eye blocking • eye rubbing • squinting • weeping and crying (children)	• Constricted • (Staring or even flashing eyes)	• head banging (often to complement spoken words or vocal interjections)	• protruded chest • squared shoulders • ears redden; then face • squared elbows • hands on hips • Hands/knees tremble	• Throat slash sign • Fists alternately opened and clenched • Palm down slam on flat surface • sweeping away objects from work surface • Stamping feet • Swearing signs	• Attack • Flee • 'plant' feet • Body erect • Pacing up and down • Body trembles • Explodes and rockets from chair	• swearing

Appendix B

Original SCALE FOR EARLY MATHEMATICS ANXIETY (SEMA)

(Wu et al., 2012)

SCALE FOR EARLY MATH ANXIETY

Instructions:
"Now I'm going to show you some math questions. I want you to read each question and pretend that you are going to answer it. Then I want you to tell me how nervous answering that question makes you feel. So remember, you do not actually have to answer the questions, but I just want you to pretend you are going to answer them and see how it makes you feel. It could make you feel not nervous AT ALL, a little nervous, somewhat nervous, very nervous, or VERY, VERY nervous.

Do you understand? Let's do one together:" Practice Item: Who's the President of the United States?

1. George bought two pizzas that had six slices each. How many total slices did George have to share with his friends?
2. Is this right? 9+7=18.
3. How much money does Annie have if she has two dimes and four pennies?
4. How do you write the number four hundred and eighty two?
5. Draw an hour and minute hand on a clock so that it would read 3:15 PM.
6. Draw a triangle and a square on the board.
7. Count aloud by 5 s from 10 to 55.
8. What time will it be in 20 min?
9. Is this right? 15−7=8?
10. Daisy has more money than Ernie. Ernie has more money than Francesca. Who has more money – Daisy or Francesca?

Instructions:
"Now I'm going to read you some sentences about situations that have to do with math. Try to pretend each situation is happening and think about how nervous it makes you feel. It could make you feel not nervous AT ALL, a little nervous, some- what nervous, very nervous, or VERY, VERY nervous. Do you understand? Let's try one. Pretend..."Practice Item: You're about to ride a roller coaster.

11. You are in math class and your teacher is about to teach something new.
12. You have to sit down to start your math homework.
13. You are adding up all the money in your piggy bank.
14. Someone asked you to cut up an apple pie into four equal parts.
15. You are about to take a math test.
16. You are in math class and you do not understand something. You ask your teacher to help you.
17. Your teacher gives you a bunch of addition problems to work on.
18. Your teacher gives you a bunch of subtraction problems to work on.
19. You are in class doing a math problem on the board.
20. You are listening as your teacher explains to you how to do a math problem.

Appendix C: Teachers' questionnaire

Evaluating computer multiplication games for Grade4-learners (9-10y)

Respondent:	V

Mathematics Teacher?	

Computer Teacher?	

Age group?	20-30y	30-40y	40-50y	50-60y	60+y

Please access the following multiplication games at:

http://www.smartygames.com/igre/math/mulMath.html (Smartygames)
http://arithmetic.zetamac.com/ (Multiplication drill)
http://www.multiplication.com/games/play/fish-shop-multiplication (Fish Shop)
http://www.multiplication.com/games/play/grand-prix-pro-multiplication (Grand Prix Pro)
http://www.arithmemouse.com/demo.html or www.youtube.com/watch?v=68tgbn_cfoI (Arithmemouse)
http://www.bigbrainz.com/Multiplication.php (Timez Attack)

Indicate your answer by using ✓ for positive response and X for negative response. It will furthermore be highly appreciated if you could comment as well.

Question	***Smartygames (Sg)***	***Multiplication drill (MD)***	***Fish Shop (FS)***	***Grand Prix Pro (GPP)***	***Arithmemouse (Am)***	***Timez Attack (TA)***	***Comments (optional reasons for your 'yes' or 'no' responses in columns 2 to 7.***
1. Will players be able to follow game instructions without having to read a manual?							
2. Does the game provide help without having to exit the gameplay level?							
3. Will the players have a sense of control over characters/avatars, interaction and movements in the game?							
4. Will they be able to feel that their actions can change the game world for the better?							
5. Are the overriding game rules clear and presented early in the game?							
6. Are the game rules, interfaces and mechanics easy to learn and use?							
7. Are the intermediate game level goals presented timeously and clearly?							

8. Are players free to use own strategies and only be prompted by the game if they should tend to fail in applying own strategy?							
9. Does the game provide a lot of sensory stimuli from different sources?							
10. Will players find the stimuli worth attending to?							
11. Will the game quickly grab player's attention and maintain their focus throughout the game?							
12. Will the players be taught how to play the game by means of tutorials that feel like playing the game?							
13. Does the game have a high workload, but still appropriate to players' perceptual, cognitive and memory limits?							
14. Will players be burdened by tasks that they do not regard as important?							
15. Do the game challenges match players' skill levels?							
16. Does it cater for individual differences and preferences?							
17. Does game challenges rise per level?							
18. Are the difficulty levels proportionate to increased skill levels of the player?							
19. Does the game prevent players from making mistakes that are detrimental to the gameplay?							
20. Are there any game elements distracting learners from the tasks they should concentrate on?							
21. Will learning in the game be boring ?							
22. Will players become emotionally attached to the game?							
23. Do players receive in-game feedback on their progress towards both game and learning goals?							
24. Do players receive immediate feedback on actions taken in the game?							
25. Is the game score or status revealed throughout the game?							
26. Will the game reward players appropriately for their effort and skill development?							
27. When errors are made, does the game provide feedback and support towards correcting errors?							
If you were to be 10y-old once again, and been given the opportunity to learn times tables by means of a computer game, which game would you choose? Why?							

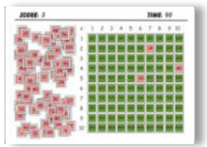
Appendix D:

Learners’ questionnaire on game criteria: *immersion*

Date of birth	

Are you a girl or a boy ?

Will you please play a game with me? Let’s pretend you are now playing each of the following games…

Smartygames	Multiplication Drill	Fish Shop	Grand Prix Pro	Arithmemouse	Timez Attack
					

Please answer the following questions as if I were to ask the questions to you while you are *actually playing* the game. (Use a × to indicate youranswer)

During which of the games (if any) will you not even hear a plane going past?	**Smartygames**	**Multiplication Drill**	**Fish Shop**	**Grand Prix Pro**	**Arithmemouse**	**Timez Attack**
During which of the games (if any) will you not even pay attention to the bell ringing for the end of the lesson period?	**Smartygames**	**Multiplication Drill**	**Fish Shop**	**Grand Prix Pro**	**Arithmemouse**	**Timez Attack**
During which of the games (if any) would you not even notice that it is freezing cold inside the classroom and that you have forgotten to put your jacket on?	**Smartygames**	**Multiplication Drill**	**Fish Shop**	**Grand Prix Pro**	**Arithmemouse**	**Timez Attack**
During which of the following games (if any) will it feel as if time is standing still and you are not even aware that a lot of time is passing?	**Smartygames**	**Multiplication Drill**	**Fish Shop**	**Grand Prix Pro**	**Arithmemouse**	**Timez Attack**
During which game (if any) can you go by what you *feel* like doing and answering- you do not only need to use your brain and *think, think* and *THINK*!	**Smartygames**	**Multiplication Drill**	**Fish Shop**	**Grand Prix Pro**	**Arithmemouse**	**Timez Attack**

Appendix E: Game description in terms of cost, content and context.

	Smartygames	Multiplication Drill	Fish Shop	Grand Prix Pro	Arithmemouse	Timez Attack
						
Game context and content	The game is about dragging the answer of a multiplication problem from the heap to the left of the playing board onto the correct square of the playing board. No time limit given. Aim of game is however to fill the board within the least amount of time.	The number range within which the answers should fall can be pre-selected. The aim of the game is to provide the highest possible number of correct answers within 120 second time limit. Player can play as many rounds as he/she wants.	Customers will be entering the fish shop. They request a fish by proposing a multiplication problem. You need to click on the tank containing the correct answer (fish). The expression of the customers face tells you whether you were correct. After two unsuccessfull attempts, customers leave in a huff Aim is to have 100% customer satisfaction.	In this racing game you race against your friends or others from around the world. Or you can engage in a private game where you race against the computer. You are to choose the correct answer to a multiplication problem at the bottom of the screen.The faster you answer correctly, the faster your car goes. If you answer incorrectly your car sends out a puff of smoke and slows down. The aim of the game is obviously to cross the winning line first.	At the start, Arithmemouse is presented with a choice of 13 doorways, one for each of the times tables from 0 to 12. Entering a doorway leads to a set of stairs, on which the chosen times table is printed. A helpful robot encourages the player to read the times table out loud as the mouse climbs the stairs. Then the challenge begins! The mouse must navigate through a series of rooms, each one containing a times table question. To pass, the player must recognize the correct answer. If the player gets it right, he can escape into the next room. If he should be wrong, he will fall into a pit and presented with the correct answer, then led back into the room with the challenge. In this way, the player is forced to get the answer right in order to progress, but if he should get it wrong, he is not left guessing. No restrictive time limit or scores provided. Aim is to open up all the “rooms”	The main character is a miniature "Shrek" and begins in a dungeon, and proceeds to a dragon's cave moodily lit, with traps and monsters. The avatar displays anxiety when faced with math problems, and jubilation when the player gets them right. The music fits well with the overall (somewhat dark) mood. The character might die, which means the player must start again from the last checkpoint reached. From time to time, there are doors with times table challenges. Behind the door, the player must answer more times table questions. At the end of the maze is a big monster (troll) who will force the player to get a whole bunch of times tables facts correct, quickly, or be sent back into the maze. When confronted with a problem, snails appear. By catching the snails, the player engages in repetitive addition that guides him to the answer. This is reinforced by throwing balls towards the sum, counting it off, before typing in the answer. The aim is to hold onto your “lives” as to discover more dungeons.

Appendix F: parent/caregiver consent form and participant assent form

NORTH-WEST UNIVERSITY
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Research Focus Area: Teaching-Learning Organisations
Faculty of Education Sciences
Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +27(018) 299-1861 (Prof. van der Walt)
Tel: +27(018) 299-2154 (Mr Jagals)

Research Topic: Grade 4 learners' anxiety during automatisation of multiplication facts in computer-assisted instructional environments

Dear parent / caregiver of ________________________________

Your child is requested to participate in above-mentioned research study. Before you agree to volunteer on behalf of your child, it is important that you take cognisance of the following:

Investigator

Azette Engelbrecht (Learning Support Coordinator, Doringkloof Primary) as part of M.Ed studies.

Study Leader(s)

Prof. M. S. van der Walt, School of Mathematics, Education Sciences, North-West University (marthie.vanderwalt@nwu.ac.za) and mnr D. Jagals, Philosophy and Research Methodology.School for Social Sciences for Education.Faculty of Education Sciences. North-West University. (divan.jagals@nwu.ac.za).

Purpose of the Research

This research study is aimed at explaining to *what extent (if any) and in what ways do computerized drill and practice (CDP) and digital game-based learning (DGBL) differ regarding its impact on grade 4-learners' confidence in their own automaticity of multiplication tables.* The outcomes of the study will also be made available to relevant GDE officials, but under no circumstances will any learner outcomes count towards your child's term or year mark.

Procedures

If your child should participate in the study, he/she will be interviewed by the researcher on how "nervous/worried" he/she will become when asked certain Mathematics problems. The interview will take approximately 45 min and will be conducted after normal school hours on **THURSDAY, OCTOBER, 2nd** from **14:00 to approx 15:00** and will not interfere with lesson periods or break times. This session will be preceded by a meet-and-greet session on **WEDNESDAY, OCTOBER, 1st from 14:45-14:15** during which the researcher will get to know the respondents (children). You (as parent) may also attend this session.

Approximately four learners may also be approached for two subsequent computer gameplay session outside school hours at school's computer centre. (You are therefore also kindly requested to answer a question on your child's computer gameplay behaviour(s) in the tear slip at the end of this letter). These gameplay sessions will be followed by two individual interviews (45 min each). These interviews will be conducted during school hours, but outside teaching contact time.

Potential Risks or Discomforts

The only risk or discomforts that your child may possibly experience could be related to a) the fact that he/she may not be familiar with the researcher as interviewer; he/she may feel uncomfortable by having to answer questions on his/her feelings about Mathematic problems without having to provide the actual answers to the problems and c) your child may feel uncomfortable being audiotaped or videotaped. The identity of your child will however not be revealed to outsiders at any point in time. If your child's responses is of such a nature that he/she can be selected for a follow-up study as explained, the researcher will then contact you as parents, once more, in order to request permission.

Potential Benefits of the Research

Depending upon the findings of the study, learners in the years to come could be offered opportunities to practice multiplication tables by means of computer games (at home and school) over and above rote memorisation methods that are currently at the order of the day.

Confidentiality and Data Storage

The outcomes of this study will not be revealed to the teacher, principal, GDE or any other learner without seeking your permission upfront.

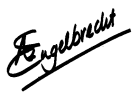
Participation and Withdrawal

Your child's participation in this research study is voluntary. He/she may refuse to participate or stop participation at any time without penalty.

Questions about the Research

If you have any questions about the research, you may contact the investigator by means of e-mail messaging (azette@msn.com) or contacting me on 082 551 5562. Keep this informed consent letter for your record.

I thank you in anticipation



Azette Engelbrecht Date: 2014-09-26

By signing and returning this tear slip to school, I acknowledge that I have familiarized myself with the content thereof and declare that….

☐ My child, ____________________, in Gr 4 __ may take part in the study as explained and….

he/she engages in computer gameplay

☐ two or more times per week or …

☐ perhaps once a week or …

☐ never

☐ My child, __________________________ may NOT partake in the study.

_______________ _____________________ ___________

Parent / caregiver Parent contact number Date

NORTH-WEST UNIVERSITY ®
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E-mail: azette@msn.com (Researcher)

LEARNER ASSENT FORM

Title: Grade 4 learners' anxiety during automatisation of multiplication facts in computer-assisted instructional environments

Background:

Hello! My name is Azette Engelbrecht. I'm here for a study on behalf of North-West University. Therefore, I would like to talk to you about Mathematics on (date to be added). I also want you to join in playing multiplication computer games on (dates to be added).

Motive:

I will be talking to you as well as a few other grade 4 learners in group sessions as well as individual sessions on how you feel about Mathematics. You will also join some gameplay sessions with another grade 4 learner. The two of you will however not form a team, nor compete against one another. The information gathered will be used to create a report to be given to the university and the education department on grade 4 learners' feelings when computer games are used when memorizing times tables.

How this works:

First I would like to ask you some questions in a group interview with 5 other grade 4 learners. It will take about 45 minutes. I will ask you some questions about Mathematics and you will be able to use pictures that may assist you in answering to my questions. Afterwards, four of you will be invited to join me after school in the computer lab for two days where we will play multiplication games on the computer. Each of these gameplay sessions will be 45 minutes.

On the following day I would like to talk to you alone about the games that you have played. If you would like, you can ask for a parent, guardian or friend to be present at any time. However, I would really appreciate it if you would answer the questions honestly and openly, so that I can find how grade 4 learners feel about times tables. Your answers are very important to me. On the last day, I will be showing you some screenshots you while playing the games. The final two sessions will once again not be longer than 45 minutes.

Precautions:

Although we talk about Mathematics during the interviews, you will not be asked to do Mathematics and provide me with answers! Your answers would only be about your feelings towards Mathematics. If any of the questions should however make you feel uncomfortable or you don't want to answer them, you do not have to. If any of the questions upset you, or if you would like to talk to someone about the feelings you experienced during the interview, please let me know and I, or another responsible adult, will be happy to assist you in feeling better about it.

Advantages:

If you decide to participate in this interview, you will have the chance to help make South African grade 4-learners' Mathematics experiences better. Even though this isn't a quick process, your thoughts and opinions are very valuable. You will also have the opportunity to learn more about ways in which you can memorize times tables.

Confirmation:

Remember, you do not have to talk about anything you don't want to. This will not affect your school work or marks or the relationship with your Mathematics teacher or any other staff member.

Disclosure Policy:

If you agree to take part in this interview, the things you tell me will be confidential. That means they will be private between you and me. Although you will be audio and videotaped, your name will not be mentioned in any report that I submit to the university and education department. The audio and videotaped files will be safely stored and not revealed to anyone except the university authorities, but only if they should request it.

Understanding:

Do you have any questions about what was just mentioned? Although all your questions may be answered for the time being, you may ask questions at any time you want. You may even choose to withdraw from the sessions if you should feel so. I will not be offended or hold it against you.

Agreement:

Would you like to participate in the research? Please indicate here with your name or a mark if you would like to participate.

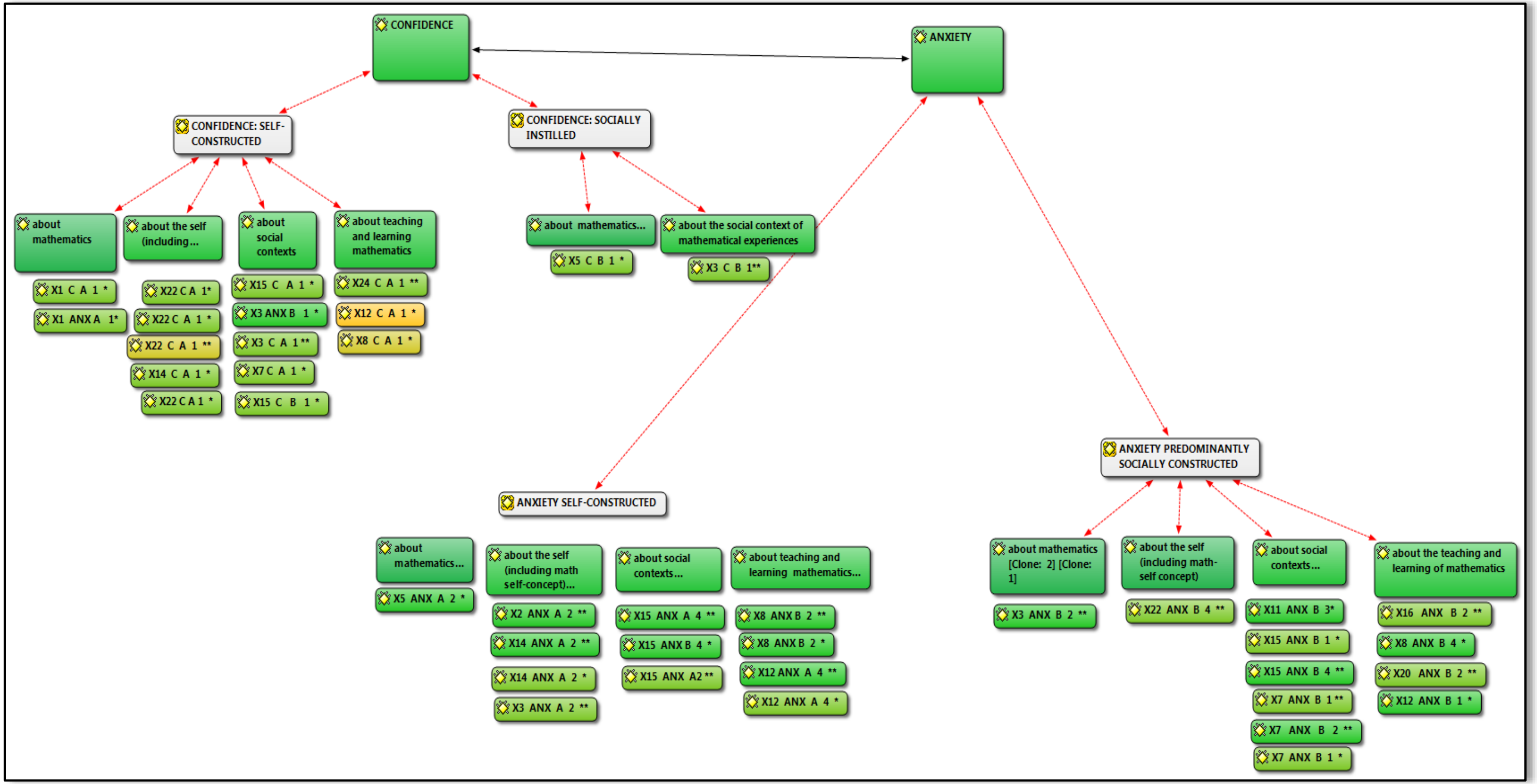
Date: ______________________________

Learner Name/Agreement: ______________________________

Researcher's Signature: ______________________________

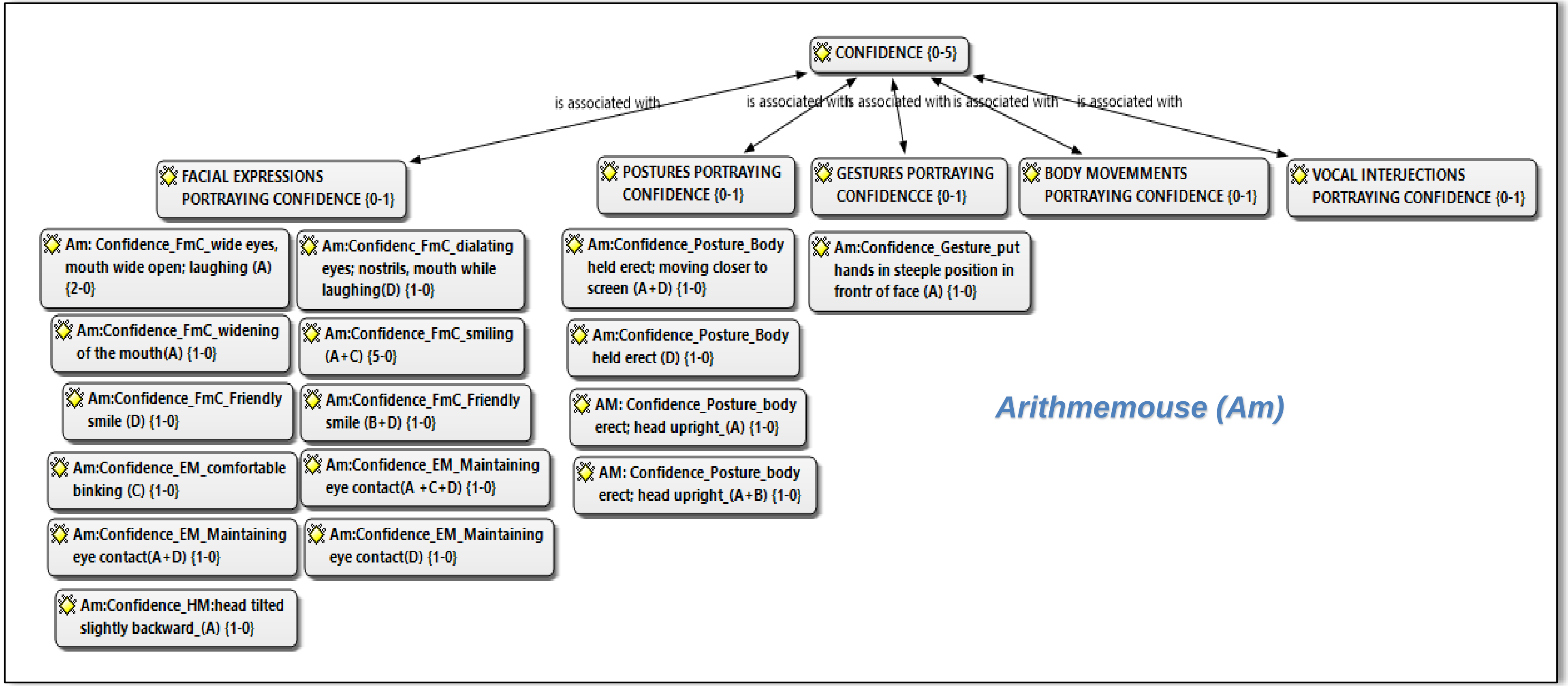
Azette Engelbrecht

Appendix G: Confidence↔ anxiety valence outlined in terms of self – or socially constructed origin

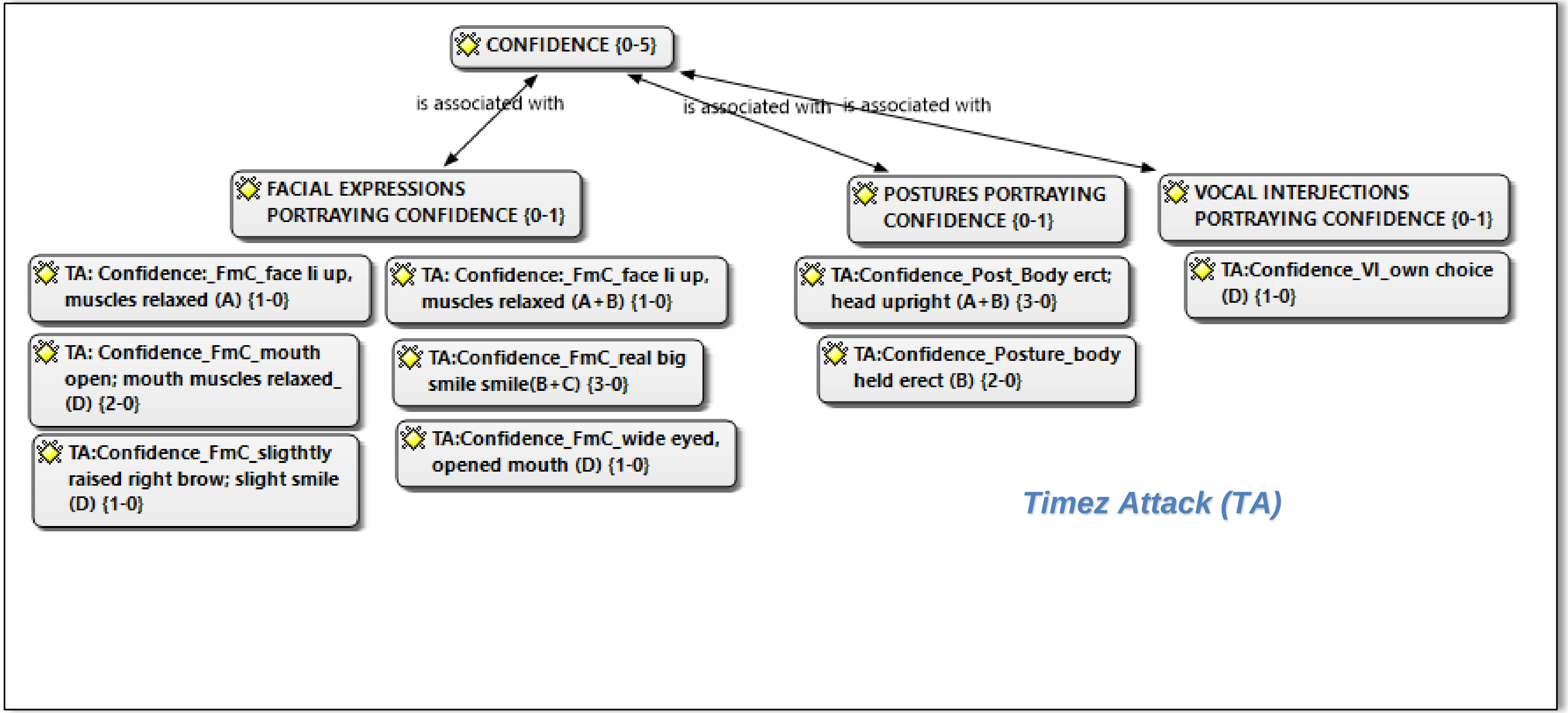


Appendix H: Network views

Observable confidence experiences while playing DGBL games: Arithmemouse (this page) and Timez Attack (next page)

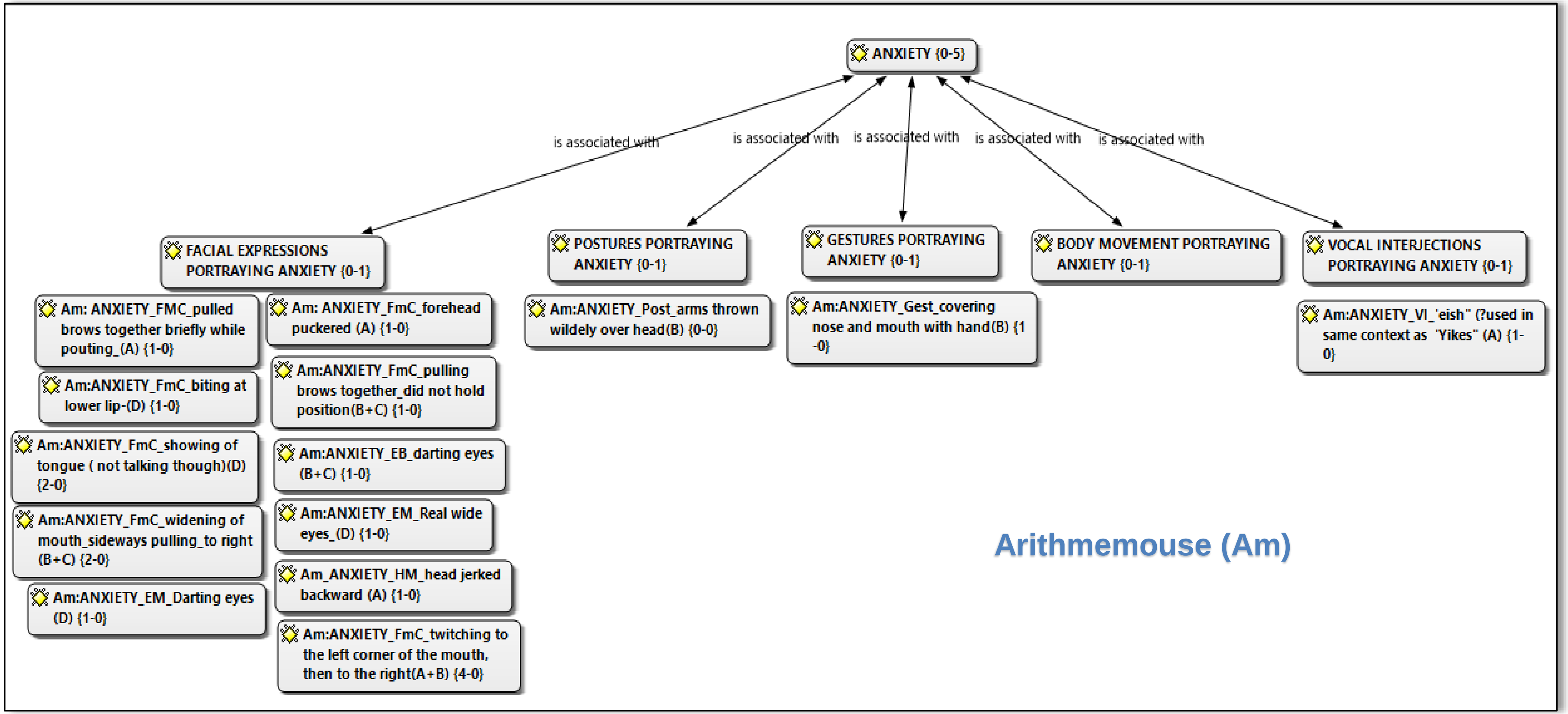


Observable confidence experiences while playing DGBL games: Arithmemouse (previous page) and Timez Attack (this page)



Appendix I: Network views

Observable confidence experiences while playing DGBL games: Arithmemouse (this page) and Timez Attack (next page)



Observable confidence experiences while playing DGBL games: Arithmemouse (previous page) and Timez Attack (this page)