

Incorporating faded worked-examples into the
mathematics classroom: exploring gender and
socioeconomic effects with two Grade 9 groups from
South Africa.

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INCORPORATING FADED WORKED-EXAMPLES INTO THE MATHEMATICS CLASSROOM:

EXPLORING GENDER AND SOCIOECONOMIC EFFECTS WITH TWO
GRADE 9 GROUPS FROM SOUTH AFRICA.

Contents

Abstract	3
Table of Abbreviations	4
1. Introduction	5
2. Literature Review	9
2.1 Human cognitive architecture.....	9
2.2 Cognitive load theory.....	12
2.3 Worked-example research	16
2.3.1 Effective worked-example design	22
2.3.2 Faded worked-examples and the completion/fading effect.....	28
2.4 Considering socioeconomic status and gender within cognitive load theory.....	31
3. Methodology	35
3.1 Participants	35
3.2 Summary of Intervention.....	36
3.3 Instruments used to Evaluate the Research Questions	37
3.3.1 Research Question 1	39
3.3.2 Research Question 2	41
3.3.3 Research Question 3	42
3.4 Collaboration.....	45
3.5 Ethics	46
4. Results and Discussion	48
4.1 Research Question 1.....	48
4.2 Research Question 2.....	56
4.3 Research Question 3.....	63
5. Conclusion	72
5.1 Summary of findings.....	72
5.2 Implications for practice	74
5.3 Evaluation of collaboration.....	75
5.4 Concluding remarks.....	76
References	77
Appendix 1: Intervention Stage 1 - Stage 7	92
Appendix 2: Stage 1 performance distribution.....	153
Appendix 3: School newsletter.....	154
Appendix 4: Letter to headteacher	155
Appendix 5: Letter to parents and parent consent for interview.....	159
Appendix 6: Ethical clearances.....	165
Appendix 7: Student performance in Stage 5 according to Quartile	167
Appendix 8: Indication of home language from Stage 2, School B	168

Abstract

Cognitive load theory details how instructional processes can be adapted to reduce unnecessary strain on working memory and improve academic performance. A main component of this theory, the worked-example effect, specifies how the use of worked-examples allows for greater learning gains compared to traditional problem-solving practices for students of low prior knowledge. This project explored the use of faded worked-examples in mathematics with two Grade 9 groups from South Africa. The aim was to explore if students of varying prior knowledge level, socioeconomic status and gender were differentially affected by completing faded worked-examples. A participatory research approach was conducted with teachers from two schools of different socioeconomic standing. Faded worked-examples were used as the medium of instruction and results on subsequent isomorphic test questions were analysed to assess the efficacy of the intervention. Surveys were also used to explore student perceptions towards the use of faded worked-examples as a learning tool. The results suggest that all students can complete faded worked-examples; however, female students were able to do so more accurately than males. Female students also outperformed males in the post-test, regardless of prior knowledge level and socioeconomic status. Most students indicated that faded worked-examples helped them learn how to simplify algebraic fractions, with more female students indicating so. Students from a low socioeconomic background also found the use of faded worked-examples more beneficial than their higher socioeconomic counterparts. Consequently, the use of faded worked-examples may improve the mathematics performance for female students and those of a low socioeconomic status. These results allude to the possibility of gender differences within cognitive load theory and worked-example research, which has not previously been documented.

Table of Abbreviations

Abbreviation	Full term
CLT	Cognitive Load Theory
SES	Socioeconomic Status
ICL	Intrinsic Cognitive Load
ECL	Extraneous Cognitive Load
GCL	Germane Cognitive Load
PKL	Prior Knowledge Level
HOD	Head of Department

Table 1: Abbreviations used in this project

1. Introduction

Cognitive load theory (CLT) suggests a number of instructional techniques that can be used in the classroom to enhance learning in the initial stages of knowledge acquisition (Paas, Renkl, & Sweller, 2004). One such technique is the use of worked-examples, which have been shown to decrease learning time and improve learning outcomes in students with a low level of prior mathematical knowledge (Kalyuga, Chandler, & Sweller, 1998; Kirschner, 2002). Atkinson et al. (2000:181) define worked-examples as “instructional devices that provide an expert’s problem solution for a learner to study” and they “consist of a problem formulation, solution steps, and the final solution itself” (Renkl & Atkinson, 2010:91). The reduction in learning time and improvement in learning outcomes due to the use of worked-examples has been termed the worked-example effect (Sweller, 2006) and has been documented in many domains, including mathematics.

During my Part 2 project, gender¹ differences in student perceptions of worked-examples became evident: high prior knowledge male students did not find worked-examples beneficial for their learning, whereas female students of all prior knowledge levels did. However, due to the limited sample size ($n = 23$) no gender differences could be inferred and, as a result, a larger sample size is incorporated into this project. Additionally, several students from a low socioeconomic status (SES)² have been admitted to my school, and many have been shown to be lacking in mathematical understanding. As a result, I also sought to explore whether or not worked-examples have the potential to assist students of differing SES and prior knowledge level (PKL).

From a national perspective, mathematics performance in South Africa is concerning, with only 22.2% of students between 2013 and 2017 achieving over 50% in their school-leaving

¹ Gender in this project refers synonymously to the sex of the student (male versus female).

² Socioeconomic status (SES) refers to the measure of one's combined economic and social status (Baker, 2014).

examinations (Department of Basic Education, 2017). This highlights that effective strategies to improve these levels of attainment are urgently required. Results from multiple studies on CLT highlight how classroom-based instruction can be tailored to improve the academic achievement of students, with the use of worked-examples offering tangible hope to those of low prior knowledge (Cooper & Sweller, 1987; Spanjers, Van Gog, & Van Merriënboer, 2012; Sweller & Cooper, 1985). However, little is known about its effect on other groups of students, such as those of different genders and socioeconomic backgrounds. As a result, this project sought to explore these avenues with the use of faded worked-examples on the simplification of algebraic fractions, and to determine if this instructional technique could be beneficial for students of South Africa.

Faded worked-examples were used as they have been shown to offer an effective transition between the initial stages of knowledge acquisition and problem-solving (Renkl, Atkinson, & Große, 2004). They are seen to begin with a complete worked-example, followed by subsequent examples where the “worked steps are faded out and instead completed by the student” (Hesser & Gregory, 2015:37). The topic of algebraic fractions was used for the faded worked-examples as it forms part of the Grade 9 curriculum, an extract of which is shown in Figure 1.

CONTENT AREA	TOPICS	CONCEPTS AND SKILLS	SOME CLARIFICATION NOTES OR TEACHING GUIDELINES	DURATION (in hours)
	1.4 Common fractions	Calculations using fractions - All four operations with common fractions and mixed numbers - All four operations, with numbers that involve the squares, cubes, square roots and cube roots of common fractions Calculation techniques	What is different to Grade 8? In Grade 9 learners consolidate number knowledge and calculation techniques for common fractions, developed in Grade 8. In Grade 9, learners work with common fractions mostly as coefficients in algebraic expressions and equations. They are expected to be competent in performing multiple operations using common fractions and mixed numbers, applying properties of rational numbers appropriately. They are also expected to recognize and use equivalent forms for common fractions appropriately in calculations and when simplifying algebraic fractions.	Total time for common fractions: 4,5 hours

Figure 1: Extract from Department of Basic Education (2011:126)

Within my practice I have also noticed that my students find the simplification of algebraic fractions difficult. As a result, it was a priority to search for a learning methodology which had the potential to reduce the perceived and innate difficulty of this topic.

Data on students' ability to complete faded worked-examples and simplify algebraic fractions was collected to determine if this learning methodology was useful. Student insights on worked-examples were also sought as this perspective is often missing from literature, despite its documented benefits for both teachers and students (for a detailed review, see Cook-Sather, 2010; Flutter & Rudduck, 2004). Additionally, by incorporating CLT practices into my classroom, I hoped also to establish whether or not results from the literature, which are often based in laboratory settings, can "persist in longer and more complex learning scenarios" (Brünken, Plass, & Moreno, 2010:264).

Considering these views and with regards to student PKL, gender and SES, the following research questions are posed.

1. To what extent are students able to complete faded worked-examples?
2. How does the use of faded worked-examples affect students' ability to simplify algebraic fractions?
3. How do students perceive the use of faded worked-examples in the classroom?

Project Outline:

To explore these research questions, a brief introduction on human cognitive architecture is offered; this forms the foundation upon which CLT is built. A review of CLT is then given, with emphasis on topics within mathematics. As the worked-example effect forms the central focus of this project, a detailed discussion on effective worked-example design is given, followed by an analysis of faded worked-example research. Evidence from my classroom is added where appropriate to substantiate the literature. As gender and SES have not been considered within worked-example research, a brief introduction is offered with specific focus on their relevance to mathematics education within South Africa. Potential links between gender and SES within CLT are also presented; however, due to the limited amount of research and restricted word count, theorised links cannot be discussed in detail. Upon completion of the literature review, the context of the study and stages of intervention are outlined. The methodology is discussed in relation to each research question with justification being provided for each stage of the intervention. Strengths and weaknesses of the methods employed are noted, as well as any relevant ethical considerations. The data is presented and discussed according to the research question it serves to inform, with a summary being provided in the conclusion. Implications for practice and a critique of the methods of collaboration are also discussed in the conclusion.

2. Literature Review

2.1 Human Cognitive Architecture

The theoretical foundation of CLT, and its suggested instructional techniques, originate from the principles of human cognitive architecture, which Sweller (2008:370) defines as the “manner in which structures and functions required for human cognitive processes are organised.” According to Sweller (2010), the five principles that govern the acquisition of knowledge by the human cognitive system are: the information store principle, borrowing and reorganising principle, randomness as generation principle, narrow limits of change principle and environmental organising and linking principle.

The basic premise of human cognitive architecture is that humans have an infinite long-term memory store (information store principle) but a very limited working memory capacity (Miller, 1956). The borrowing and reorganising principle suggests that information stored in long-term memory is firstly acquired from other individuals and then reorganised into schemas, based on the knowledge already held in long-term memory. The term *schema* (plural schemata or schemas) is seen as a single mental entity comprising of various sources of related information that can be constructed or deconstructed based on new sources of information (Piaget, 1953). The randomness as genesis principle posits that when an individual is faced with a problem that cannot be solved by their existing long-term schemas, a random position is taken and evaluated to see if it aids in the solution of the problem. If this random position proves useful, an initial schema is developed and adapted through ongoing trials. When students are exposed to new information or mathematical techniques, the narrow limits of change principle states that few elements can be simultaneously processed in working memory and information can only be stored for a short period of time; thus, creating new and amending existing schemas takes place gradually. This principle also highlights why learning in mathematics requires a significant amount of time and mental investment.

The environmental organising and linking principle “explains how we can transfer massive amounts of organised information from long-term to working memory to effect the complex actions required of the human cognition” (Sweller, 2010:38). This principle states that when new information is linked or combined with existing schemas in long-term memory, it is more readily recalled. Unlike the narrow limits of change principle, the environmental organising and linking principle deals with knowledge that is already organised into schemas in long-term memory. Consequently, there are no known limits to the processing of these schemas in working memory (Sweller, Ayres, & Kalyuga, 2011). This makes it important for teachers to link existing schemas with new knowledge; for example, to assist students in the learning of algebraic fractions, the teacher would need to prompt a recall of their existing schemas about how to simplify fractions and algebra in order to enable the linking of these existing schemas with the new knowledge.

In his review on working memory, Baddeley (2012:4) states “[t]he term “working memory” evolved from the earlier concept of short-term memory” which is seen to only be able to store information for a limited time. On the other hand, working memory can both store and process information. Documented limitations in the development of schemas highlight that working memory may be one of the central limiting factors for learning (Baddeley, 1992). The multi-component model of working memory (Baddeley & Hitch, 1974; Baddeley & Logie, 1999) comprises of a “[l]imited capacity central executive system that interacts with a set of two passive subsystems... the speech-based phonological loop and the visuo–spatial sketchpad” (Raghubar, Barnes, & Hecht, 2010:111). The degree of learning, in general, is moderated by a central executive which is seen to be “the most complex component of working memory” (Baddeley, 2012:13) and is able to focus and divide attention, switch between tasks and serve as a temporary storage capacity for approximately four pieces or chunks of information. The term *chunk* was first used by Miller (1956) in an effort to differentiate between *bits* of

information, that are individual items such as the word 'seven', and *chunks of information*, being multiple bits of related information, such as the numbers 2, 3, 5, 7, 11, 13, which are all prime numbers. Chunks of information can thus be recalled as a single entity in working memory, as opposed to multiple, isolated bits of information. This is similar to the *action* and *object* knowledge acquisition stage of APOS theory (Asiala et al., 1996), which will be discussed in more detail, and interwoven with CLT, later on in this review.

Although working memory capacity is seen to be predictive of mathematical ability (LeFevre, DeStefano, Coleman, & Shanahan, 2005), there are mixed results as to which component of working memory is primarily associated with mathematical achievement (Friso-Van Den Bos, Van Der Ven, Kroesbergen, & Van Luit, 2013; Raghubar et al., 2010). This is mirrored by Raghubar (2010:119) who states: "[w]e have not said much ... about potential interactions between working memory and mathematics instruction because not much data exists to guide our thoughts." In addition to these mixed results, most of the research that explored the association between working memory and mathematical achievement did so with primary school students. Thus, there is even less literature detailing any potential differences in working memory provisions between students of different ages and between different topics in mathematics. Despite this, many studies have shown a correlation between working memory and performance (LeFevre et al., 2005; Peng, Namkung, Barnes, & Sun, 2016; Raghubar et al., 2010) with programmes such as Cogmed™ and Jungle Memory™ claiming to improve mathematical performance by improving working memory (Memosyne Ltd, 2011; Pearson, 2016). However, a distinction needs to be made between *improving* working memory and *increasing* it, as many studies appear to use these words synonymously. An *improvement* in working memory can be viewed as a more efficient use of a fixed working memory capacity, whereas an *increase* alludes to working memory capacity being plastic in nature.

As working memory is seen to process visual and text-based information separately, caution must be taken when generalising worked-example research from these two areas. Results based on topics with a high visuo-spatial element, such as geometry, may involve different working memory components compared to those that have a high textual element such as algebra. Additionally, these working memory components may change altogether when these topics are combined. Differences in working memory have also been reported between males and females, with females displaying greater verbal and written capabilities (Hedges & Nowell, 1995; Lewin, Wolgers, & Herlitz, 2001) and males greater mathematical and visuo-spatial abilities (Kaufman, 2007; Lynn & Irwing, 2008). As working memory functioning, and its associated limitations, form the central core of CLT, potential gender differences within this framework have been suggested by Bevilacqua (2017). Subsequent to a brief overview of CLT and worked-example research, the reasons for the inclusion of gender differences within this framework are discussed in Section 2.4.

2.2 Cognitive load theory

Developed by John Sweller in the 1980s, CLT is primarily concerned with the interplay between working memory and long-term memory in learning. Sweller (1988, 1989) suggested that the mental effort imposed on students when they solve problems with no initial guidance leaves little room for understanding and schema acquisition. It is from these beginnings that CLT took the central notion that learning materials should minimise working memory load to enhance learning (Plass, Moreno, & Brünken, 2010). In a brain-imaging study of nine individuals between the ages of 18 and 39, Callicott et al. (1999) showed that when task difficulty increased, greater activity was measured in specific areas of the brain. However, once very high levels of cognitive load were experienced, the network of brain activity broke down and resulted in reduced task performance. Thus, it is important that unnecessary cognitive load be minimised in learning. The three main types of cognitive load that are seen

to limit working memory are intrinsic, extraneous and germane load, which will henceforth be discussed in more detail.

Intrinsic cognitive load (ICL) is defined as a mental load that occurs because of the innate difficulty of the material, in other words, “it is imposed by the basic characteristics of information” (Sweller, 1994:6). It is determined by two factors: the level of difficulty of the information, often determined by the level of elemental interactivity (Paas, Renkl, & Sweller, 2003), and the knowledge available in long-term memory. The level of element interactivity is determined by the number of elements that working memory must hold and process simultaneously (Sweller, 2010). For example, simple addition such as $2 + 3$ is an operation with low elemental interactivity for a Grade 9 student in contrast to a Grade 1 student. The Grade 9 student is considered an expert in this area as they have already completed many of these operations, thus acquiring a well-developed, automated schema for addition. On the other hand, the Grade 1 student is a novice with little experience, or possession of well-developed schemas, in this type of operation. As a result, when working on this operation, elemental interactivity may be high for a Grade 1 student, causing a greater load on their working memory due to a lack of established schemas available for recall. This is emphasised by Leppink (2017:2) who states that “more advanced learners will probably experience a lower ICL... because they can activate more developed and perhaps already more automated cognitive schemas than their less experienced peers.”

Knowledge available in long-term memory is often referred to as *prior knowledge* and is defined as being “the amount of task-relevant elements already available in the learner’s mind” (Brünken, Seufert, & Paas, 2010: 195). This has important consequences in mathematics when students fail to acquire information in previous grades, as this increases the intrinsic load of materials in subsequent years. As a result, students with low prior knowledge in fractions and algebra may experience a higher ICL when working with algebraic

fractions. It has also been suggested that ICL may be dependent on student aptitudes such as age (Paas, Camp, & Rikers, 2001), information processing speed (Fink & Neubauer, 2001), memory span and verbal and spatial abilities (Mayer & Sims, 1994; Plass, Chun, Mayer, & Leutner, 1998). However, the discussion of these variables is beyond the scope of this literature review.

Extraneous cognitive load (ECL) is “imposed purely because of the design and organisation of the learning materials” (Sweller & Chandler, 1994:192). Schnotz and Kürschner (2007) identified four main types of ECL: the degree of interaction between important information, maintenance of information in working memory, and the level of interaction between irrelevant information and waste of time and effort. There are also various documented cognitive load effects that result from poorly-designed instructional materials, such as the *split attention effect* (Tarmizi & Sweller, 1988), *modality effect* (Mousavi, Low, & Sweller, 1995), *redundancy principle* (Sweller, 2005) and the *expertise reversal effect* (Kalyuga, Ayres, Chandler, & Sweller, 2003). These effects will be discussed with regards to worked-example design in Section 2.3.

Germane cognitive load (GCL) was introduced to CLT sometime after the studies on intrinsic and extraneous load by Sweller, van Merriënboer and Paas (1998). It is defined as being a load that results from the beneficial processing of new information into new or existing schemas (Leppink, 2017). In other words, GCL encompasses all mental loads that are required for mental schema construction and understanding and, unlike intrinsic and extraneous load, is associated with positive learning gains and should be maximised within a lesson.

The three types of cognitive load are seen to comprise the entirety of working memory capacity (Baddeley, 2012). However, their respective levels may vary as depicted in the

additivity hypothesis shown in in Figure 2 by Leppink et al. (2015:210). Within this hypothesis, unallocated working memory resources are seen to be devoted to germane load.

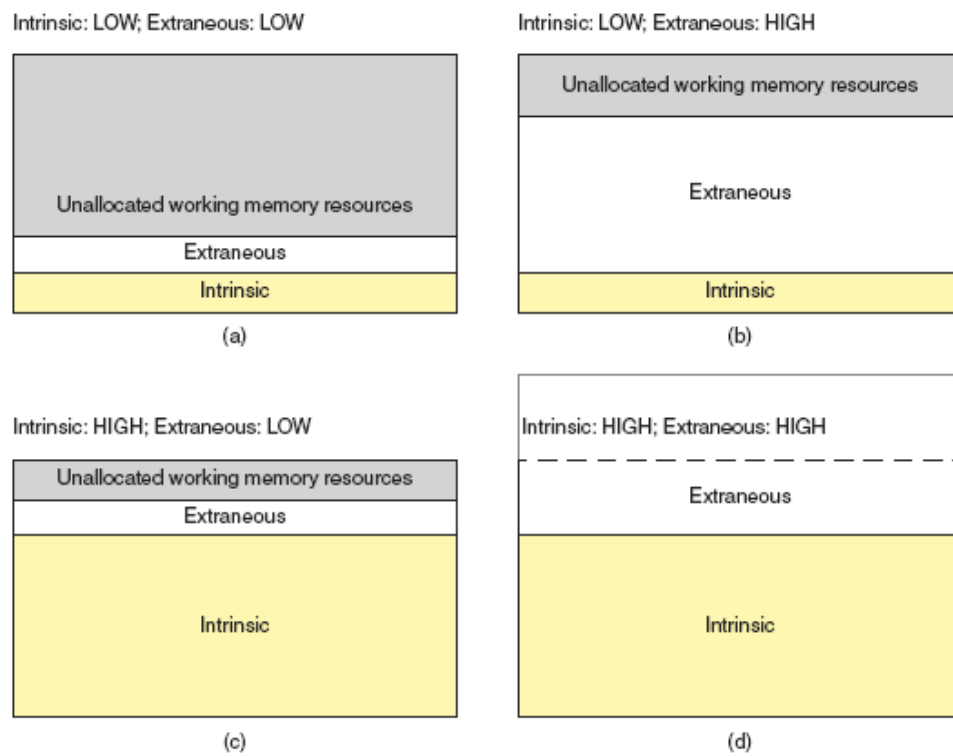


Figure 2: Cognitive loads experienced as posited in the Additivity Hypothesis

In analysing condition (a) in Figure 2, both ECL and ICL are reduced to maximise unallocated working memory resources to GCL – out of the four conditions shown, this is seen to be the most desirable for learning. There are many documented ways that ECL and ICL can be reduced in order to maximise GCL, with most suggestions being within the context of worked-example research. Leppink (2017) and Seufert et al. (2007) also report that there are different ways of minimising intrinsic and extraneous load, depending on the skill level of the student, allowing for greater allocation of working memory towards the processing of content.

According to Sweller (1988), the most effective way of decreasing ECL is through the use of worked-examples, which will henceforth be discussed.

2.3 Worked-example research

Renkl and Atkinson (2010:91) state that “[o]ne of the classic instructional effects associated with CLT is the *worked-example effect* in cognitive skill acquisition”. The use of examples as a learning tool is not a new phenomenon, with archaeological evidence of some of the earliest mathematical works illustrating their use by the ancient Egyptians, Babylonians and Chinese (Gillings, 1972). Bills et al. (2006) documents that modern day evidence of the use of worked-examples in mathematics can be found in Swetz’s (1987) account of the 1478 Treviso Arithmetic text which has been described as “the earliest known, dated, printed arithmetic book” (Swetz, 1985:XV). Today, worked-examples can be found in every mathematics textbook.

Results have shown that the use of worked-examples often results in improved learning gains when compared to traditional problem-solving strategies for students of low prior knowledge (Cooper & Sweller, 1987; Sweller & Cooper, 1985). These learning gains associated with the use of worked-examples is termed the worked-example effect and was first documented by Sweller and Cooper in 1985. In the final of three experiments by Sweller and Cooper (1985), twenty Year 9 students from Australia were shown how to manipulate algebraic expressions using three worked-examples and divided into two groups: a conventional problem-solving group and a worked-example group. During the second phase, termed the “acquisition phase” (Sweller & Cooper, 1985:73), both groups were given four identical questions; the conventional problem-solving group had to solve the questions as one would traditionally do in a textbook exercise, whereas the worked-example group had the worked-solution to the first and third problems presented to them. Results indicated that students assigned to the worked-example group took significantly less time to process questions in both the acquisition and post-intervention test phase. These students also made fewer mathematical errors, defined as being “any algebraic transformation that violates the rules of algebra” (Cooper &

Sweller, 1985:76). In conclusion, Cooper and Sweller (1985) postulate that conventional problem-solving strategies inhibit schema formation in algebra, whereas the study of worked-examples enhances the initial stages of schema acquisition. Atkinson, Derry, Renkl, and Wortham (2000:183) elaborated further on this initial research and state:

When presented with traditional practice exercises, students tended to employ typical novice strategies, such as trial and error, while students presented with worked-examples before solving often employed more efficient problem-solving strategies and appeared to focus on structural aspects of problems.

In focusing on the structural aspects of problems, ECL may be reduced, negating the need to expend mental resources on repeated trial-and-error approaches. In doing so, Atkinson et al. (2000) suggest that the rate of schema development can be improved. As a result of further investigation, Kirschner, Sweller, and Clark (2006) believe that minimally guided practices, such as discovery and problem-based learning, do not consider the structure of human cognitive architecture that proposes working memory resources become overloaded when students must search for the correct methods to use. As a result of these findings, Kirschner, Sweller, and Clark (2006:80) propose that “worked-examples are the epitome of strongly guided instruction... [and] provide some of the strongest evidence for the superiority of directly guided instruction over minimal guidance”.

Staying within the field of mathematics, the worked-example effect has subsequently been documented in many global instances: learning how to translate word equations into algebraic expressions with 15-17 year-old students from the United States (Carroll, 1994), the solving of linear equations with Grade 7 Indonesian students (Rentowati, Ayres, & Sweller, 2017), the simplification of fractions, factorising, simplifying exponential expressions and the solving of geometry problems with 5th, 7th and 8th Grade students (Zhu & Simon, 1987), problem solving based on three geometrical theorems with Grade 8 and 9 female students from Australia (Bokosmaty, Sweller, & Kalyuga, 2015), and problem solving in Geometry with

Grade 9 students in Australia (Wong, Lawson, & Keeves, 2002). Due to the presence of the worked-example effect in many mathematical domains, it is hypothesised to also be present with Grade 9 students from South Africa in learning how to simplify algebraic fractions with faded worked-examples.

However, the analysis of worked-examples has only been shown to be an effective way of learning how to perform well-structured problems (Atkinson et al., 2000; Große & Renkl, 2006; Sweller et al., 1998) which “consist of a well-defined initial state, a known goal state, and constrained set of logical operators” (Jonassen, 1997:68). This type of question is the dominant form that is found in South African school textbook exercises, an extract of which can be seen in Figure 3.

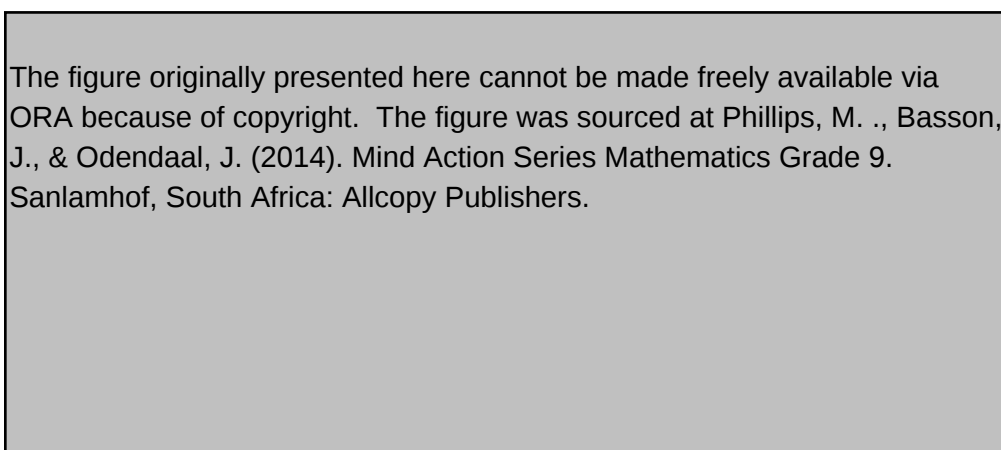


Figure 3: Extract from a South African textbook (Phillips, Basson, & Odendaal, 2014:41)

Furthermore, caution must be exercised in using worked-examples, as students often do not analyse the example for underlying structures and, instead, glance over it without much thought (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). As a result, students must be engaged with the worked-examples in order to derive the associated benefits from them. Gog, Paas, and Van Merriënboer (2004) have posited that one way of doing so is for students to complete the missing steps of a problem or worked-example. This strategy is known as a

faded worked-example approach (Renkl, Atkinson, Maier, & Staley, 2002) and is discussed in more detail in Section 2.3.2.

However, worked-example research does not advocate the use of this method for those who have well-developed schemas – a notion epitomised by Atkinson, Derry, Renkl, and Wortham (2000:185) who state “...learning from worked-examples is of major importance in *initial* stages of cognitive skills acquisition.” An explanation as to why worked-examples mostly benefit students with underdeveloped schemas is suggested within the scope of APOS theory (Asiala et al., 1996). This theory (being an acronym for Action, Object, Process, Schema) details the hierarchal stages of mathematical knowledge development. In his summary of APOS theory, Inglis (2015) postulates that students begin with learning an *action*, or a set of rules. Once actions become unconsciously automated, they develop into a *process* which can then be applied to novel situations. Processes then become an *object* when they can adapt to a variety of novel situations and create new actions. When acting cohesively, actions, processes and objects are seen to be encapsulated into a *schema*.

Although APOS theory was originally developed to model mathematical knowledge acquisition in undergraduate students, it has also been linked to elementary mathematical thinking in arithmetic and algebra (Tall, 1999). Considering this applicability, APOS theory may provide a basis for understanding why worked-examples assist secondary school students with poorly-developed schemas. In terms of APOS theory, a schema can only develop once a student has constructed a mental action, process and object. A worked-example may provide the external cues that allow a student to take an action, which would then allow for the development of a process, object and, finally, a schema. This aligns with the research that emphasises that worked-examples are only beneficial for students in initial stages of skill acquisition and those that have poorly-developed schemas (Atkinson et al., 2000; Renkl, 2002). As a result, worked-examples may enhance the initial action stage of

APOS theory, with problem-solving following suit to enhance the development of objects and schemas. This notion is depicted in Figure 4, which suggests that the use of worked-examples should be phased out as a student moves from action to process to object, with a problem-solving approach dominating learning nearer to schema development.

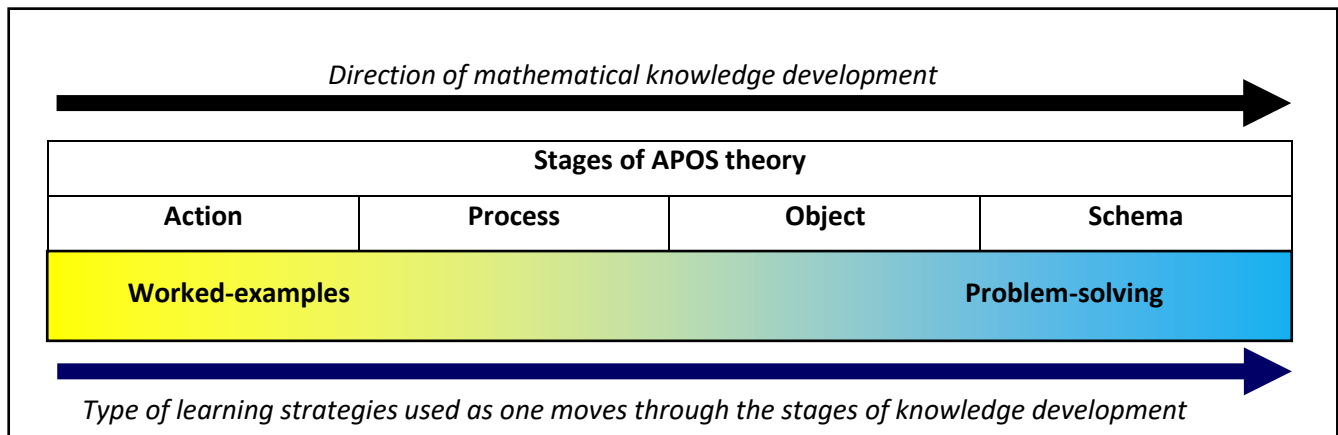


Figure 4: Worked-example and problem-solving strategies used with APOS theory

Although worked-examples are seen to assist students with limited schemas only (Cooper & Sweller, 1987; Spanjers et al., 2012; Sweller & Cooper, 1985), no distinction has been made between medium to high PKL students who have well-developed schemas of deep, connected and coherent knowledge (Richey & Nokes-Malach, 2014) and those who have unidentified misconceptions within these well-developed schemas. Misconceptions are defined as “mistakes that impede learning” that “produce[s] a systematic pattern of errors” (Smith, DiSessa, & Roschelle, 1994:116,119). Within mathematics, student misconceptions are seen to arise through the incorrect generalisation, and application, of existing knowledge to novel situations (Resnick et al., 1989). The correction of misconceptions in mathematics is of paramount importance as Sewell (2002:24) states, “if new information does not fit with what students already know they may simply choose to reject it outright, leaving our classrooms having learnt nothing”. In support of Sewell’s statement, the identification and correction of misconceptions has been found to improve learning in decimal fractions

(Resnick et al., 1989) and algebra (Booth & Koedinger, 2008). Within my practice, I have also found that the correction of misconceptions enhances learning; however, when students realise they have *many* misconceptions, they sometimes give up completely.

Literature documenting the ability of worked-examples to correct misconceptions is varied, with Richey and Nokes-Malach (2014:198) stating that, “there is little evidence that practice or worked-examples promote coherence or help learners resolve misconceptions.” Conversely, in research done by Carroll (1994:365) with Grade 9 students in mathematics, the author states that “students actively used the worked-examples to self-correct mistakes and to monitor their understanding.” Further research on the use of self-explanations with worked-examples also shows promise in rectifying these misconceptions (Chi, De Leeuw, Chiu, & Lavancher, 1994). In addition to these findings, 67% of high PKL students and 60% of low PKL students in my Part 2 project indicated that some of their misconceptions in algebra and fractions were made apparent using self-explanations to worked-examples. These results suggest that worked-examples may assist high PKL students in correcting their misconceptions, thus also allowing for improvement in their learning and performance. However, these misconceptions may be so small that they do not reflect in any significant learning gains. Additionally, they also may not inhibit students in attaining the correct answer.

Further development in worked-example research has included the analysis and interpretation of instructional explanations provided within each step of a worked-example (Renkl, 2002; Wittwer & Renkl, 2010), elicitation of written and spoken self-explanations (Bielaczyc, Pirolli, & Brown, 1995; Chi et al., 1989; Hodds, Alcock, & Inglis, 2015), identification and explanation of errors in incorrect worked-examples (Siegler, 2002) and the completion of missing steps of the solution process in faded worked-examples (Hesser & Gregory, 2015; Renkl et al., 2004). Each of these approaches have shown positive learning gains in a variety of learning fields, primarily due to their presumed ability to reduce the ECL

of the learning material. However, each type of worked-example may comprise of different intrinsic and extraneous loads, thus making it very difficult to decide on which type of example to use with students of different PKLs. Additionally, despite the many benefits associated with the use of worked-examples, there are also many negative effects that result from their ineffective design.

2.3.1 Effective worked-example design

Effective worked-example design is primarily concerned with the reduction of ECL, with earlier research suggesting that the “intrinsic cognitive load... is fixed and innate to the task” (Ayres, 2006:389). However, recent updates to CLT have questioned the concrete state of ICL. Aspects of worked-example design that have shown to reduce ECL and ICL are thus discussed below.

Mayer and Chandler (2001) suggest that ICL can be decreased by dismantling complex learning materials into smaller pieces, otherwise known as *segmenting*. The authors show that when instructional material on lightning formation was segmented, it enhanced learning for college students. However, caution must be taken here as Mayer and Chandler’s concept of segmenting was used with reference to multimedia-based worked-examples and not those presented on paper, as mostly used in a classroom. Additionally, both the age range of the subjects and the subject matter is substantially different to those of this study. Positive learning gains have also been found by Spanjers, Van Gog, and Van Merriënboer (2012) in their study involving the segmentation of animated worked-examples on probability calculations with fifty-two Dutch students with a mean age of 14.62 years. As a result, the intrinsic load of learning materials may be lowered using worked-examples, if segmenting is used effectively.

Again focused on multimedia studies, the *pre-training principle* suggests that ICL can also be reduced when students receive foundational training before learning a topic (Moreno & Mayer, 2010; Pollock, Chandler, & Sweller, 2002). Thus, if students receive training about how to simplify fractions and algebra before they commence the simplification of algebraic fractions, their existing mental schemas may be more readily recalled and adapted to the task. Mayer and Moreno (2010:145) state that the reason for the efficacy of the pre-training principle lies in the notion that “knowledge in working memory can be used by the learner to help chunk the incoming material, effectively decreasing cognitive load”. However, caution is noted in the applicability of this principle to paper-based mathematics lessons, as it has not been documented within this context. Despite this, it is common practice in classrooms to present prior knowledge before introducing a new section – this can also be seen to initiate schema recall and may elicit similar effects as the pre-training principle.

The notion that ICL is not fixed is further explored by Schnotz and Kürschner (2007) who believe that intrinsic load is only fixed with regards to the expertise levels of the students, the specific learning activity and its objectives. However, they believe that ICL varies with regards to the instructional design and tasks need to be selected based on the PKL of individual students. In other words, tasks that are too difficult may impose too high an ICL, ultimately causing cognitive overload. Conversely, tasks that are too easy will impose too low an ICL and would result in students not learning anything new, thus, wasting time and mental resources. As a result, within the additivity hypothesis, attaining low levels of ICL and ECL will be different for students of different prior knowledge. Therefore, learning materials should increase ICL for high PKL students and decrease ICL for low PKL students, a notion which is depicted in Figure 5. In doing so, this may increase unallocated working memory space for GCL and improve learning.

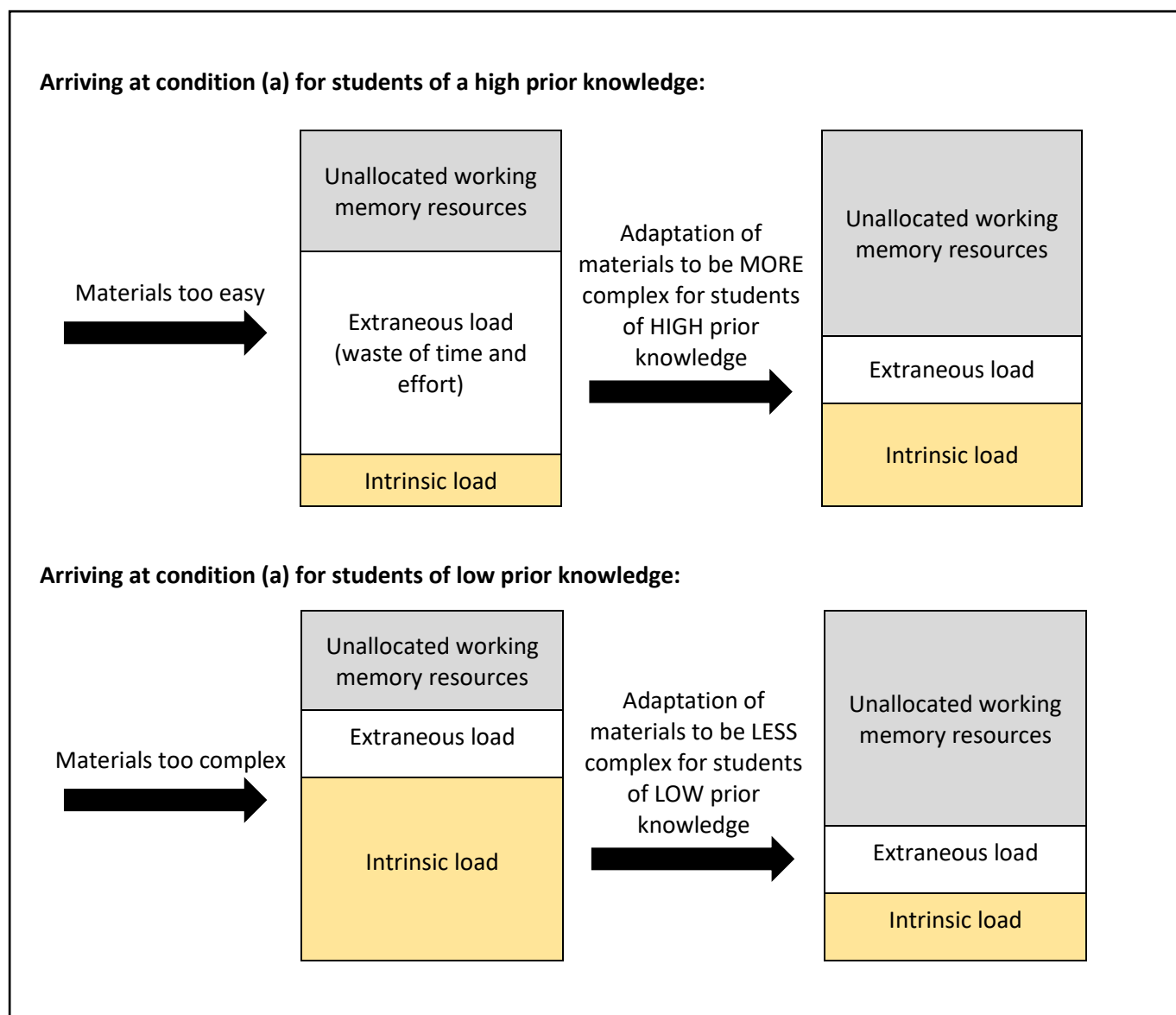


Figure 5: Adapting the Additivity Hypothesis based on students of different prior knowledge

This highlights the importance of knowing the PKLs of students before designing learning materials. However, the tailoring of these materials for students of different PKLs poses a formidable task for the teacher of a mixed-ability class, as they will need to create different pieces of work for different students.

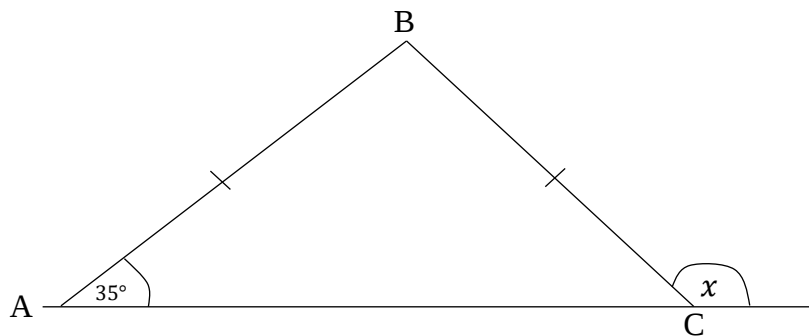
When there are too many elements that a student needs to simultaneously hold and process in working memory, an ECL can occur. Additionally, when students process elements that are not necessary for learning, a further ECL can occur due to the interactivity between irrelevant

information – this is seen to be the leading cause of the redundancy effect (Sweller & Chandler, 1994). The redundancy effect occurs when “sources of information that do not contribute to schema acquisition or automation interfere with learning” (Sweller, 2010:30). Factors such as verbose directives from an instructor (Lafleur, Côté, & Leppink, 2015) and distractions in the immediate environment (Lafleur et al., 2017) have been shown to overload working memory in medical students. Despite Lafleur’s subjects being older than those in this study, these factors have not only impacted my own ability to make sense of problems, but I have also witnessed their impact on my students.

When different pieces of information interact, one needs to hold one piece of information in working memory whilst simultaneously processing the other, causing an ECL (Schnotz & Kürschner, 2007). Working memory was previously thought to be able to hold only seven to nine pieces of information (Miller, 1956) but recent upgrades suggest that we are only able to maintain and process between three and five pieces of information (Cowan, 2001, 2010). This suggests that instructional materials should not be separated spatially as this would require the simultaneous holding and processing of information, causing an increase in ECL. This is known as the split-attention effect and it “occurs when the learner’s attention must be split between multiple sources of visual information that have to be integrated for comprehension because the individual sources cannot be understood in isolation” (Schnotz & Kürschner, 2007:471). Figure 6 illustrates the split-attention effect in two geometry examples of the same question. Both examples show how to calculate the missing angle ' x ', however in Condition 1 the text is separated from the image, whereas in Condition 2 the textual explanations are incorporated into the image, thus reducing the need to split cognitive capacity between the two elements.

Question:

Determine the size of the angle labelled x .



Condition 1: Causing split-attention effect

$AB = BC$, therefore $\triangle ABC$ is isosceles

$\therefore \angle ACB = 35^\circ$ (base angles of an isosceles triangle are equal)

$\therefore x = 180^\circ - 35^\circ$ (adjacent supplementary angles)

$\therefore x = 145^\circ$

Condition 2: Reducing the split-attention effect

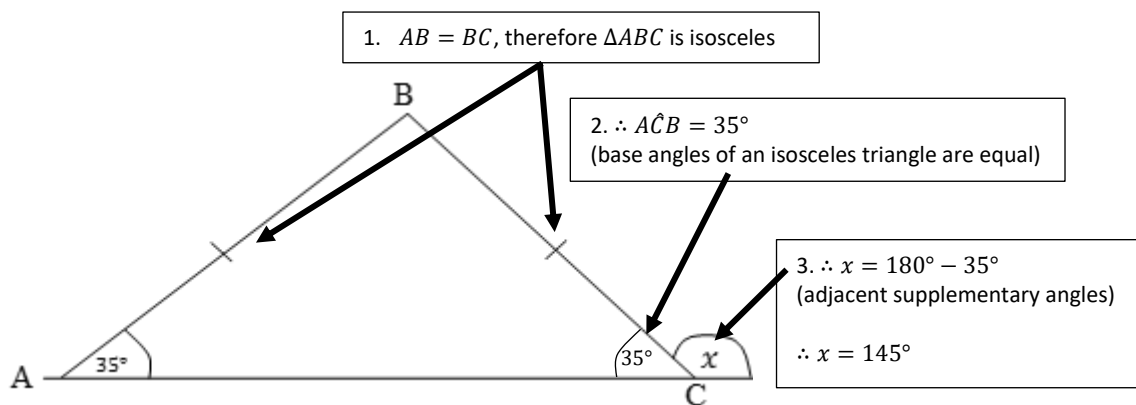


Figure 6: Illustration of the split-attention effect and how to reduce it

Caution must be taken when incorporating text with images as too many interacting elements may cause a cognitive overload. However, the modality effect may alleviate this problem as studies have shown that when textual information is replaced with audio, a lowered extraneous load occurs, resulting in improved learning (Mayer & Chandler, 2001; Mousavi et

al., 1995; Tindall-Ford, Chandler, & Sweller, 1997). Another way of avoiding this confusion is by guiding students to the most important information that needs to be processed through the use of colour or the bolding and italicising of text, otherwise known as the signalling principle (Harp & Mayer, 1998; Mautone & Mayer, 2001).

When students with well-developed schemas waste time and effort by processing unnecessary information, they often underperform – this is most commonly referred to as the expertise reversal effect (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Schnotz & Kürschner, 2007). Evidence of the expertise reversal effect is most apparent when students of high PKL analyse worked-examples (Kalyuga et al., 2001). Teacher intervention may be required in these instances to encourage high PKL students to actively select only the information they feel should be processed; however, the effectiveness of this strategy has not yet been documented.

There is little evidence to suppose variation in cognitive loads as a result of the differential interaction with worked-examples. This is emphasised in the meta-analysis by Wittwer and Renkl (2010), in which they report that although learning gains were experienced through the incorporation of instructional explanations with worked-examples, the degree to which these were greater than those provided through the use of self-explanations is unclear. However, examples that require interaction, such as faded worked-examples, and those that require self-explanations and error identification have shown to be the most effective in supporting learning in the classroom (Atkinson, Renkl, & Merrill, 2003; Chi et al., 1994; Große & Renkl, 2007; Renkl et al., 2004). As this project is focused on the use of faded worked-examples, these will now be discussed in greater detail.

2.3.2 Faded worked-examples and the completion/fading effect

Hesser and Gregory (2015:36) state that “[f]aded worked-examples are similar to worked-examples but fade out steps for students to complete, allowing support within the problem-solving approach as learning improves.” Thus, as students progress in knowledge acquisition and schema development, they should complete the missing steps of faded worked-examples in which “the number of blanks is increased step-by-step until the whole problem needs to be solved” thus providing a “smooth transition from studying examples, to working on incomplete examples, to problem solving” (Alexander Renkl & Atkinson, 2010:99). This technique is called a *fading procedure* or the *fading effect* (Renkl & Atkinson, 2010:100), which has also been termed the *completion effect* by Paas and Merrienboer (1994). Faded worked-example design has been described in one of two ways: forwards versus backwards fading (Alexander Renkl, Atkinson, Maier, & Staley, 2002) and slow versus fast fading (Reisslein, Sullivan, & Reisslein, 2007).

The concept of faded worked-examples and forward and backward fading was first introduced by Renkl et al. (2002), who posited that as the level of student knowledge increases the guidance offered in instruction should decrease. In their study with two Grade 9 Physics classes in Germany, they employed the use of both backward and forward faded worked-examples. In backward faded worked-examples, the first example is complete, the second has the final step omitted and the third has the final two steps omitted – this process continues until only the problem state is left. Forward faded worked-examples follow in a similar manner; however, the first step of the example is incomplete, followed by the first and second steps in the subsequent example, and so on, until only the problem state is left. The authors found that both types of faded worked-examples promoted learning and performance in similar questions (near transfer), but backwards faded examples offered greater performance measures in a post-test. The use of self-explanation prompts, as well as backward faded

examples, have also been shown to foster learning in both near and far transfer problems (Renkl & Atkinson, 2003), with far transfer problems being structurally different to those previously encountered. However, this study was conducted with college students who may have a more advanced level of cognitive functioning than middle or high school students.

The notion of slow and fast fading was introduced by Reisslein et al. (2007) with engineering students of varying levels of prior knowledge, between the ages of 17 and 39. They assigned students of low, middle and high prior knowledge to one of three conditions: slow, fast or immediate fading. In the fast fading condition, students worked through four backwards faded worked-examples on electrical circuits, with the fourth only presenting the problem state. In the slow fading condition, students worked through eight backwards faded worked-examples with the seventh and eighth examples presenting only the problem state. In the immediate condition, students were presented with four problems with no faded worked-examples to complete. Perceptions of the students towards the fading approach were also measured. The study found that a slow fading condition was beneficial for students of low prior knowledge, but fast fading or immediate fading for students of high prior knowledge. With regards to student perceptions, the low and medium prior knowledge students were found to be “significantly more positive towards the usefulness of the instructional strategies employed... than their high prior knowledge counterparts” (Reisslein et al., 2007:53). These results provide further evidence that the use of faded worked-examples may benefit students of low PKLs as they progress in their understanding.

In the previous section, the use of worked-examples and problem-solving strategies was positioned within the stages of APOS theory, with worked-examples being used during the action phase and problem-solving strategies in the schema development phase. Renkl (2014:125) states that “a tried-and-tested method for structuring the transition from studying worked steps to problem-solving is to gradually fade worked steps.” Therefore, the use of

faded worked-examples can be seen to promote knowledge acquisition between the first and last phases of knowledge development within APOS theory, as demonstrated in Figure 7.

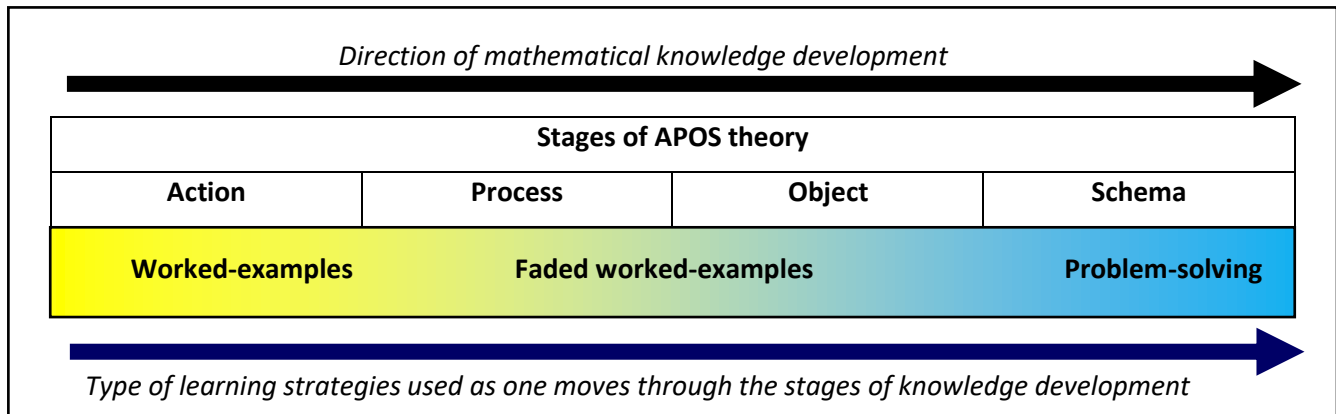


Figure 7: Positioning of faded worked-examples within APOS theory

By changing the structure of the worked-example, the learning materials are adapted to students at different stages of learning. As a result, faded worked-examples may impose a higher intrinsic load than full worked-examples, but a lower intrinsic load than problem-solving questions. This aligns with the notion that intrinsic load is not fixed according to the difficulty level of the material, but more to the knowledge levels of the students working with the materials (Schnotz & Kürschner, 2007). Thus, the use of worked-examples may benefit students of both low and intermediate prior knowledge, with the former studying full examples and the latter incomplete examples.

Considering the information provided in this literature review, worked-examples mostly benefit students of a low prior knowledge. What is not known is the extent to which this is true for students of different genders and SES, both of which are present in my classroom. A brief synopsis on the effects of SES and gender within CLT is henceforth discussed, as it forms a central focus of this study.

2.4 Considering socioeconomic status and gender within Cognitive Load Theory

Socioeconomic status (SES):

According to the results published by the 2015 Trends in International Mathematics and Science Study (TIMSS), South Africa is ranked 37th out of 39 countries in mathematics performance of Grade 8 level students (Reddy et al., 2016). Coupled with this, the South African test scores varied widely within the country which is indicative of “high educational inequalities which mirror the societal inequalities” (Reddy et al., 2016:7). Extending this outlook, the 2015 TIMSS study found public school performance in mathematics was significantly lower than that of independent schools which reinforces the notion of great societal and educational inequalities. This poor international standing in mathematical achievement and high variation between students is a cause for concern, highlighting that mathematics performance within South Africa needs to be addressed urgently.

The logical starting point for this address lies in the factors that affect the learning of mathematics. However, a basic search for literature highlights that there are numerous documented factors which influence mathematical learning. These factors are grouped into three organisational levels: individual, school and demographic (Saritas & Akdemir, 2009). Factors that affect learning at the individual level are prior mathematical knowledge, anxiety and motivation; at the school level, the type of school and the resources used; and, at the demographic level, gender and SES. These represent only a small selection of affecting factors; however, they are the most pertinent to this study.

South African students of a low socioeconomic status have frequently been shown to have substandard performance in mathematics (Mullis, Martin, & Foy, 2016; “TIMSS 2011 Assessment,” 2013). As a natural progression from CLT research, poor performance alludes to the possibility of poor schema formation (Piaget, 1953; Sweller & Cooper, 1985). As worked-examples have been shown to promote schema acquisition in students of low prior

knowledge, it is natural to suggest that this learning methodology may improve the learning of students from a low socioeconomic background. In line with this, Zhu and Simon (1987) suggest that worked-examples may be able to teach students content without direct instruction from the teacher. This may be important in schools with many students in a class, such as those found in low socioeconomic areas in South Africa, as teachers will not be able to assist students as readily as when class sizes are small. This is emphasised by Kariuki and Guantai (2005:5) who state, “[t]here is some evidence that in smaller classes, teachers devote more time to student support.” In their paper, Kariuki and Guantai (2005) analyse the data set from the 2000 SACMEQ study with Grade 6 students across several African countries, including South Africa. Part of their analysis found relatively strong negative correlations between class size and mathematical achievement in Grade 6, providing further evidence that an increase in class size may impact the degree of teacher assistance, as well as student learning. However, as these students are almost three-years younger than those in this study, similar effects may not be found. Aligned with this, in analysing the TIMSS-R dataset, Howie (2003) found class size was not a significant predictor of mathematics performance, with significant predictors instead being student exposure to and use of the English language in the classroom, as well as their SES.

These results indicate that there may be many factors associated with student performance, with SES being included in these. As a result, the potential of worked-examples to enhance learning for students of both high and low SES is further explored in this study.

Gender:

Current research in CLT suggests that our biological makeup, as shaped by evolutionary processes, may affect the way males and females think, learn and understand (Geary, 2008; Paas & Sweller, 2012). In line with this, Bevilacqua (2017:190) postulates that the biological differences between male and female brains is suggestive of differential cognitive processing

and states that “[t]here is enough evidence in the literature to support the inclusion of gender differences in cognitive load as a further upgrade to cognitive load theory.”

Although gender differences have seldom been discussed within CLT, brain-imaging studies have exhibited structural variations in female and male brains (Cosgrove, Mazure, & Staley, 2007; Zaidi, 2010) with learning and memory differences between males and females being additionally suggested (Andreano & Cahill, 2009). With regards to South African mathematics performance in the TIMSS 2015 study, Reddy et al. (2016) found that although females outperform males, no significant differences were evident. Additionally, meta-analytical studies on gender and performance in mathematics have found little international difference between males and females, except in problem-solving where “a gender difference favouring males emerged in high school” (Hyde & McKinley, 2012:1125). Aligned with this, high achieving 15-year-old male students outperformed high achieving females in mathematics in all of the countries surveyed in PISA 2012 (OECD, 2015). However, this trend was only seen at high levels of proficiency and, on average, female students outperformed males. The OECD (2015) report also states that female students reported lowered self-efficacy and confidence levels and higher anxiety rates in mathematics compared to male students, which may be a contributing factor to the performance differences seen. As no African countries participated in PISA 2012, it may be difficult to generalise these results in a South African context. Nevertheless, they may provide some insight into any gender differences found within CLT research.

Despite how small these gender differences might be, I have found that the female students in my class function differently to males, with females generally appearing to be more conscientious and diligent. Additional results from my Part 2 project also indicated that more female students, regardless of PKL, preferred the use of worked-examples. This further

emphasises that male and female students may approach learning differently and alludes to possible gender differences in CLT.

Of interest to note is that females have been found to outperform males significantly in reading and, out “of the 40 countries that participated in PIRLS 2006, South Africa had the third largest (pro-girl) gender gap” (Van Broekhuizen & Spaul, 2017:6). Reading ability has also been shown to be directly related to mathematics ability in secondary school Dutch students (Korpershoek et al., 2015) and within the last three round of PISA results (Akbasli, Sahin, & Yaykiran, 2016). Thus, it may also be important to acknowledge the impact of language on mathematics performance in South Africa, which has eleven official languages.

Considering these views, this project seeks to explore how SES and gender may impact on worked-example research in a South African classroom setting. However, as previous research has clarified that worked-examples mostly benefit student of low PKLs (Cooper & Sweller, 1987; Sweller & Cooper, 1985), the research questions used to explore this are further analysed with reference to this. The three research questions, analysed according to student PKL, gender and SES are thus:

1. To what extent are students able to complete faded worked-examples?
2. How does the use of faded worked-examples affect students' ability to simplify algebraic fractions?
3. How do students perceive the use of faded worked-examples in the classroom?

3. Methodology

This project followed a participatory research approach in which the teachers “implement[ed] interventions to bring about change, development and improvement to their lives, acting collectively rather than individually” (Cohen, Manion, & Morrison, 2011:37). However, improvement in learning was also sought for students, with the efficient design and implementation of learning materials forming the central core of this project.

3.1 Participants

As this project was an extension of work done in Part 2, my Grade 9 class of twenty-three mixed-ability students (twelve male and eleven female) between 14 and 15-years-old was used as a pilot study and completed the full intervention. The results and student commentary from this were used to amend the materials for the main intervention with the Grade 9 cohort from two other schools, described below.

School A is a co-educational, independent day school which admits students of a high SES³. Five teachers took part with one hundred and fifteen Grade 9 students (forty-five males and seventy females). This school was selected as it is formed part of a group of schools to which my own school belonged, and connections with the Head of Department (HOD) of mathematics had already been established.

School B is a co-educational, public day school which admits students of low SES³. There are one hundred and ninety-two Grade 9 students in total with ninety-four males and ninety-eight females, split into four classes. Three teachers, including the HOD, took part. Based on several discussions with the mathematics teachers, only two of the four classes (n=108; fifty-nine males and forty-nine females) were included in the study. This was due to the large number of students, and associated cost of printing all the research materials.

³ Students from a high SES are seen to be represented by those in School A, and those of a low SES from School B. Results from Stage 2 confirm this assumption, but due to word count limitations cannot be presented in this project.

3.2 Summary of Intervention

Both schools followed an intervention which comprised of seven stages as summarised in Figure 8. These stages are discussed in Section 3.3, with reference to how they are used to evaluate each research question. Appendices are page-referenced and hyperlinked throughout the document for ease of reference.

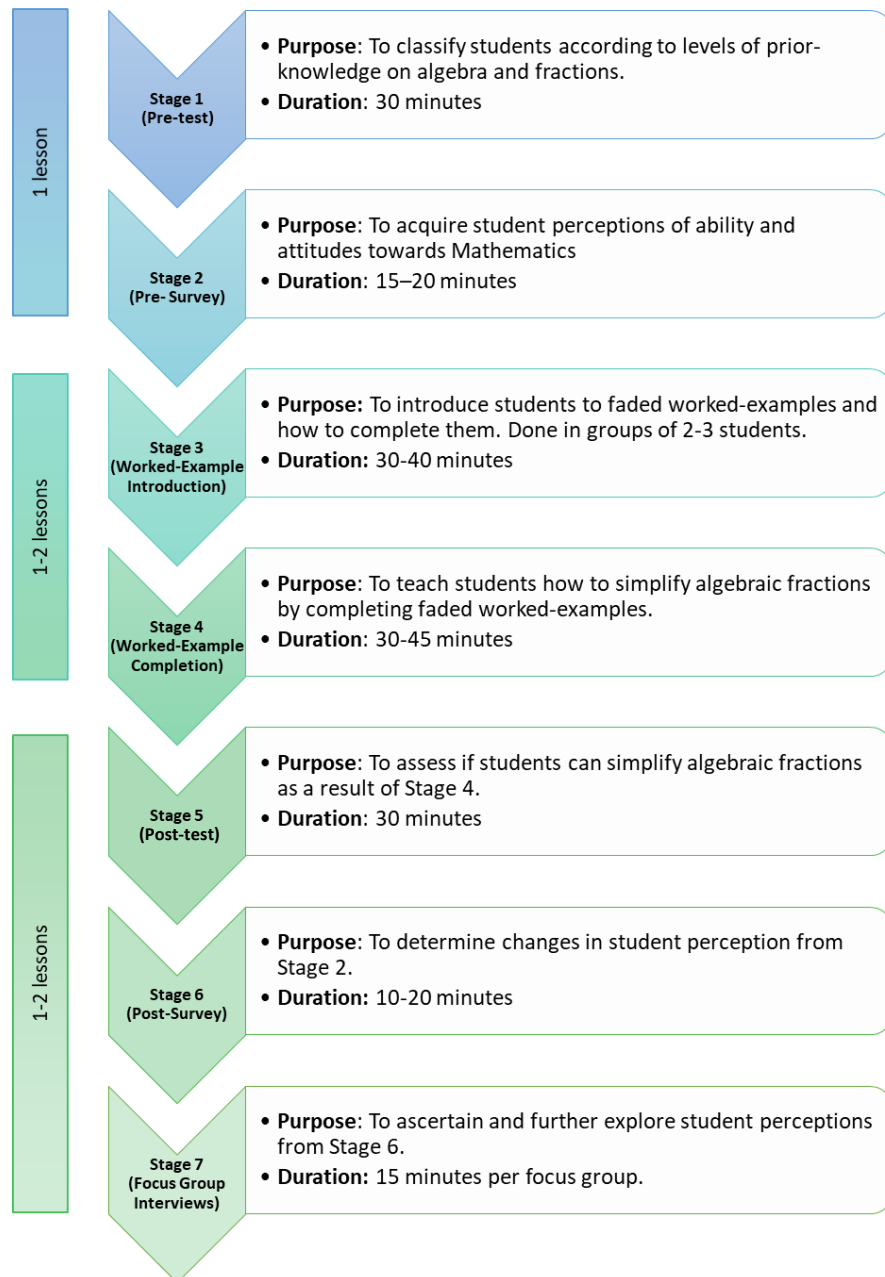


Figure 8: Summary of Intervention

3.3 Instruments used to Evaluate the Research Questions

Used to evaluate all three research questions, Stage 1 determined student PKLs in fractions and algebra (see Appendix 1, page 97). Questions for Stage 1 were selected from the Trends in International Mathematics and Science Study 2011 Grade 8 Mathematics Assessment Items (“TIMSS 2011 Assessment,” 2013). As done by Reisslein et al. (2007), students were sorted into three PKLs, based on their performance: low prior knowledge (PKL1), medium prior knowledge (PKL2) and high prior knowledge (PKL3). The cut-off values for these categories are outlined in Table 2. Validity issues are noted here as it proved a difficult task to distribute students equally to three categories as performances varied considerably (see Appendix 2, page 153). Aligned with this, Reisslein et al. (2007) suggest that student PKL classification is an area that needs further consideration, as it is not consistent throughout CLT literature.

Prior-knowledge Level	Performance in Stage 1
PKL1	0-54%
PKL2	55%-70%
PKL3	71% - 100%

Table 2: Cut off values of student prior-knowledge classification

To reduce the loss of teaching time in trialling this intervention, student results from Stage 1 were collected using Zipgrade (ZipGrade LLC, 2018) and distributed to the teachers. As only half of the students from School B completed the full intervention, extra copies of Stage 1 were distributed to all students of School B for inclusion in their term assessments.

Although not directly linked to a specific research question, Stage 3 was included to prepare students in using faded worked-examples. During Stage 3, students were introduced to faded worked-examples on simplifying fractions and algebra (see Appendix 1, page 114). These topics were not combined at this stage. As detailed by the pre-training principle (Mayer &

Moreno, 2010), this was done to ensure all prerequisite knowledge had been covered before students attempted to simplify algebraic fractions in Stage 4. Furthermore, all materials were printed in colour to reduce ECL as detailed by the signalling principle (Harp & Mayer, 1998; Mautone & Mayer, 2001).

In line with faded worked-example design, which states that the initial examples should be fully completed, Stage 3 comprised of completed examples that students analysed in groups of two to three. Results from my Part 2 project indicated that students preferred to work in pairs during this stage. In doing so, they could create meaning and understanding together (Damon & Phelps, 1989) and were able to explain the examples to one another, instead of attempting to self-explain. This was also done as self-explanation in worked-examples has been shown to promote learning as long as students can observe and describe the underlying structures of the example (Chi et al., 1994; Wong et al., 2002). Thus, instructional explanations were included in the worked-examples to assist students in identifying these underlying structures, as detailed by Wittwer and Renkl (2010).

As Baars et al. (2017) posit that worked-examples are most effective when followed by isomorphic problem pairs, a set of five structurally similar questions were included after each example in Stage 3. As the correction of student understanding is paramount for the effective use of worked-examples (Sweller & Cooper, 1985), answers were also included to allow students to check their calculations. Despite the fact that students were able to check their answers and seek assistance from their teacher at this stage, the extent to which they did so is not known and highlights a potential weakness in the design.

All figures, tables and statistical calculations in this project were done using Microsoft Excel.

3.3.1 Research Question 1

To what extent are students able to complete faded worked-examples?

This research question was evaluated according to how well students completed the worked-examples in Stage 4 with student perceptions on the difficulty of each example allowing for a deeper analysis into levels of cognitive load. Data was analysed according to PKLs, gender and SES.

Prior research has demonstrated that more than three worked-examples need to be used for the worked-example effect to be apparent (Renkl, 2014b). Thus, eight worked-examples, presented in order of increasing complexity, were used in Stage 4 (see Appendix 1, page 124). As done by Reisslein et al. (2007), faded worked-examples in Stage 4 were only awarded one point if the faded steps, as indicated by square brackets [], were correct. See Appendix 1, page 127 for an illustration. Equivalent answers were also marked correct. Worked-example 1 was not included in the analysis as it did not involve the simplification of an algebraic fraction.

After each worked-example in the pilot study, students indicated both their level of mental load and the question difficulty using two 9-point Likert scales. The mental effort scale was originally designed and used by Paas and Van Merriënboer (1993) and Paas et al (2003) and the question difficulty scale was adapted from this. This mental effort rating scale has been extensively used in CLT research; however, its reliability has been criticised as it does not differentiate between different types of cognitive load and does not take into account other factors such as “motivation, ability, expectations, training, timing, stress [and] fatigue” (Kantowitz, 1987:97). Despite these claims, the mental effort rating scale by Paas et al. (2003) is relatively simple for students to understand and complete. During the pilot study, my students believed that the mental effort and question difficulty scale measured the same entity

and, when probed further, preferred using the question difficulty rating. As a result, only the difficulty rating scale was used to determine the level of mental load invested in completing each faded worked-example.

To identify the source of cognitive load, students also indicated why they found the examples difficult by selecting one of the options shown in Figure 9, with each corresponding to a specific type of negative cognitive load.

<i>If you found it hard, please indicate why:</i>		Type of Cognitive Load
	The instructions were confusing	ECL
	I couldn't work out the numbers	ICL
	I don't know how to do fractions	ICL
	I don't know how to do algebra	ICL
	There were too many bits of information and I got confused	ECL
	I use a different method so I had to think hard about how this method was working	ECL
	The examples were too long and I couldn't focus till the end	ECL

Figure 9: Categories of cognitive load

Chi et al. (1989) and Zhu and Simon (1987) found that when students engage deeply with worked-examples, they exhibit positive learning gains without the assistance of a teacher. Thus, to ascertain if the faded worked-examples allowed for similar learning gains, no teacher assistance was allowed during Stage 4. A potential weakness in methodological design is noted here as students may give up completely if they require a large amount of teacher assistance, thus causing significant data loss. Although this did not occur during this intervention, it may still be an area of consideration for future studies.

It is hypothesised that students will be able to complete the given faded worked-examples in Stage 4; however, this may differ according to PKL, gender and SES.

3.3.2 Research Question 2

How does the use of faded worked-examples affect students' ability to simplify algebraic fractions?

To evaluate this research question, it was first established whether or not overall student performance had been affected by the faded worked-examples in Stage 4. To do so, a comparison of student performance between Stage 1 (pre-test) and Stage 5 (post-test) is illustrated with a scatterplot to highlight any changes in performance after completing faded worked-examples. For these scatterplots, a linear association was not presumed - thus, a model of best fit was chosen for each set of data from School A and B. Additionally, the Pearson product-moment correlation coefficient is calculated between Stage 1 and Stage 5 to determine any possible association between student performances. Secondly, a deeper analysis of student performance in Stage 5 is provided, with large differences in results between PKL, gender and SES being highlighted. As no statistical tests were conducted between Stage 1 and Stage 5, a potential weakness is noted as no statistical differences in the student performances can be inferred. Despite this, the overall trends and differences can still be discussed in relation to existing literature and provide a useful starting point to explore possible gender and socioeconomic differences in CLT research.

According to Atkinson, Renkl, and Merrill (2003), students who learn from worked-examples should be able to solve questions with similar surface features. Thus, a seven-question assessment (Stage 5) was issued upon completion of Stage 4 (see Appendix 1, page 142). The degree of student learning was determined by their performance in this assessment. Questions included only the problem state, with similar surface features to the worked-examples given in the intervention. However, during the design phase of the intervention, the HOD from School A suggested that a question that assessed far transfer be included. As a result, Question 5 of this Stage was similar, but not identical, to the questions from Stage 4.

Each answer in Stage 5, even if not fully simplified, was awarded one-point. As was the case for Stage 1, extra copies of Stage 5 were given to the teachers of School B, thus allowing them the option to include these results in the terms assessments.

Due to the breadth of research in this area, it is hypothesised that students will be able to learn how to simplify algebraic fractions using faded worked-examples, especially those students with low prior knowledge. However, the extent to which this occurs for students of different gender or SES is not known.

3.3.3 Research Question 3

How do students perceive the use of faded worked-examples in the classroom?

To evaluate this research question, three sources of data were used. From Stage 6, student perceptions on whether faded worked-examples helped them learn how to simplify algebraic fractions, or not, was reported on first. Student perceptions on the identification of their prior misconceptions by using faded worked-examples were then used to explain these results. Finally, student perceptions of whether or not they would like faded worked-examples to be used again is analysed. Commentary and interview data from Stage 6 and 7 were used to support any suggestions made.

Stage 2 and 6 were analysed using paper-based questionnaires. This method was chosen over an online format as students from low socioeconomic backgrounds may not have access to electronic devices. However, there are several limitations associated with the use of paper-based surveys: students may interpret the survey questions and rating scales differently and questions may be omitted or incomplete (Cohen, Manion, & Morrison, 2011b). To minimise this, teachers were asked to check the surveys before they were collected. Students may also not know how to answer the survey questions (Dörnyei & Taguchi, 2011), which is especially

important when surveys are not conducted in the respondent's home language (Howie, 2003). This was not raised during the pilot study and is an area for further consideration.

Questions from Stage 2 and 6 were adapted from the TIMSS 2015 Grade 8 Student Questionnaire and the PISA 2012 Mathematics Assessment (Mullis et al., 2016; OECD, 2013). As there was no research available on student and teacher perceptions of the use of worked-examples, these questions were adapted from my Part 2 project. An "even number scaling system" was used in most of the questions from Stage 2 and 6 (Cohen et al., 2011b:389) to ensure students selected an opinion that best suited their own, rather than a middle value which would not provide useable, valid and reliable data. In Stage 6, students self-reported on several questions pertaining to their views on the use of faded worked-examples. Based on discussions with my students in the pilot study, the categories used within the rating scale were amended and checked to be "discrete... to exhaust the range of possible responses" (Cohen et al., 2011b:368).

Students were asked in Stage 2 and 6 if they would like to be interviewed. This was done to enable a deeper exploration into student perceptions of faded worked-examples and to allow the students to "become an active part of the process of analysis" (Kitzinger, 1995:300). Semi-structured interviews (Stage 7) were conducted to further enhance the data from Stage 6. As most of the students indicated a preference for a group interview in Stage 1, the interviews comprised of two focus groups with four to five students to promote discussion and ensure that the students felt comfortable (Cohen, Manion, & Morrison, 2011c). Participants in this focus group were randomly chosen, but it was ensured that both males and females from different prior knowledge groups were included. However, in doing so, student hierarchal structures may impact on the efficacy of the group discussion (Kitzinger, 1995). Roulston, DeMarrais and Lewis (2003) suggest that interviews should be conducted in an area where

there is little chance of interruption. However, two interruptions occurred during one focus group interview for School B, highlighting a potential weakness in the data collection process.

To establish if students believed that faded worked-examples helped them to learn how to simplify algebraic fractions, the categories of “kind of” and “definitely yes” were combined in the analysis of this question from Stage 6. Only the category of “yes” was used in the analysis of whether or not students would like worked-examples to be used again in class. To explain these results, students were asked to indicate if they identified any prior misconceptions after the intervention. Within this category, they had four options from which to choose; the positive options of “Yes, but only a few times” and “Yes, there were many times” were combined for ease of reference. Percentages were then reported according to school (SES), gender and PKL. Attention was paid to student perceptions of how faded worked-examples assisted in correcting their prior misconceptions in certain topics and it is suggested that, in correcting these misconceptions, students may perceive faded worked-examples as beneficial to their learning.

It is hypothesised that students will perceive the usefulness of faded worked-examples differently according to PKL, gender and SES. However, the extent to which the perceived usefulness varies according to PKL, gender and SES is unknown.

3.4 Collaboration

As the nature of participatory research is to allow for “equal control of the research by both participants and researchers and the movement towards change through empowerment” (Cohen, Manion, & Morrison, 2011:38), both students and teachers were involved in the design and implementation of this project. Student views were considered as the elicitation of student perceptions has been shown to allow teachers a different perspective on their practice (Flutter & Rudduck, 2004). Additionally, by allowing my students to comment on the materials in the pilot study, I could clarify certain items to ensure their meaning would not be misinterpreted.

Before the intervention took place at School A, the methodological design was discussed with the HOD. During this session, worked-examples and assessment questions were adapted to suit Grade 9 students. Due to time constraints, I was unable to meet with the other four Grade 9 teachers, but the HOD explained the study and distributed the research materials to them. Validity issues are acknowledged here, and to minimise potential miscommunication, each set of materials included instructions for the teachers to follow (see Appendix 1, page 93). However, I met with both the HOD and Grade 9 teachers from School B, where I explained the methodology and clarified any misunderstandings. As collaboration formed a central tenet of the project, teacher perceptions were also sought from all those involved and analysed using paper-based questionnaires. All student and teacher questionnaires were kept in a locked cabinet.

A copy of my project was submitted to both schools upon completion and a summary was also shared with the wider community in my school newsletter (see Appendix 3, page 154). Results of my Part 2 project were shared at the Education Association of Southern Africa’s Conference in January 2018 and the results of this project were shared at the World Education Research Association Conference in August 2018.

3.5 Ethics

Schenk and Williamson (2005) provide five ethical principles by which research with children should abide. These are outlined below in relation to the specific context of this project:

Consent and participation. Written consent was obtained from both head teachers (see Appendix 4, page 155) and all teachers were informed of the nature of the research project and its aims. However, details of worked-example research were not discussed to ensure teacher or student perceptions were not influenced. However, it was mentioned that both positive and negative effects had been found and would be shared upon completion. Meetings were conducted outside of school hours to ensure teaching time was not jeopardised. Students were introduced to the research project by their teachers and informed that they would remain anonymous and could opt out of the research at any time. Written parent consent was acquired for students who took part in the audio-recorded interviews (see Appendix 5, page 159).

Power relations. Differences in power between the students, teachers and myself were acknowledged and considerable effort was made to ensure the students felt comfortable. To account for this in the interview, I gave the students a brief introduction to myself and ensured that there were no right or wrong answers. As stipulated by Cohen, Manion, and Morrison (2011c), I also encouraged them to discuss the questions in their group to allow them to feel at ease and more comfortable with the process.

Legal and professional regulations. This project gained ethical approval from the University according to the guidelines stipulated by the British Education Research Association (BERA, 2011). Ethical approval was also obtained from the Western Cape Education Department as part of the research done in this project took place in a public school (see Appendix 6, page 165).

Vulnerable children. This was an important consideration for the students in School B, but the teachers confirmed that no particularly vulnerable children took part in the study.

Culture and gender considerations. After South Africa's liberation from the Apartheid regime, Archbishop Desmond Tutu described the country as a Rainbow Nation (Kellerman, 2014). This phrase encapsulates the multiculturalism of South Africa – a country with eleven official languages. Thus, careful acknowledgement of cultural and gender-norms were considered in the design of this project. However, due to the innate multicultural composition of South African schools, a weakness is noted in that not all cultural backgrounds could be considered. However, in collaboration with the teachers and HODs, sensitive issues and possible biases were avoided where possible.

4. Results and Discussion

The results are presented and discussed according to the research question they serve to explore.

4.1 Research Question 1

To what extent are students able to complete faded worked-examples?

Results from Stage 1 allowed for the classification of students according to their PKLs. The student distribution within these levels, further differentiated according to gender, are shown in Table 3.

		School A	School B
Low prior knowledge (PKL1)	Male	7	17
	Female	24	11
Medium prior knowledge (PKL2)	Male	9	28
	Female	24	22
High prior knowledge (PKL3)	Male	29	7
	Female	18	14

Table 3: Distribution of student numbers according to school (SES), prior knowledge and gender.

The low numbers of male students in PKL1 and PKL2 for School A and PKL3 for School B are noted with regards to the poor generalisability of the data. Limitations are also noted due to the large discrepancies in student numbers within each division.

Figures 10a and 10b show the average performance in Stage 4 between males and females in School A and B, respectively. Throughout the analysis of this research question, the performance of students in Stage 4 refers to their ability to complete the faded worked-examples.

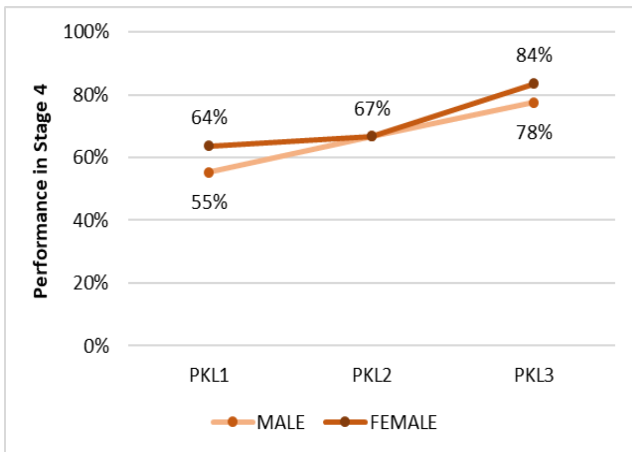


Figure 10a: Stage 4 Performance, School A

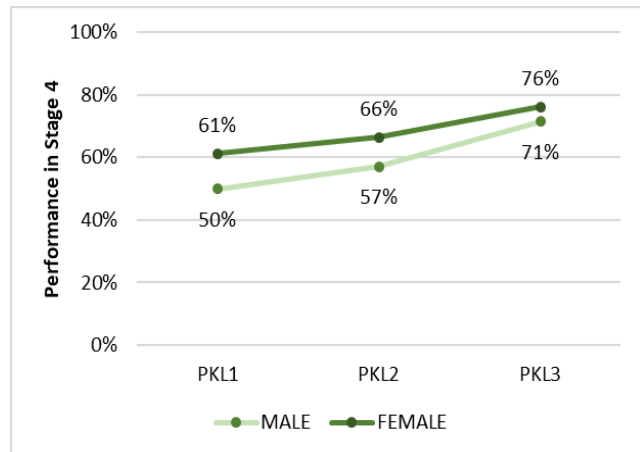


Figure 10b: Stage 4 Performance, School B

Apart from PKL2 for School A, females outperformed males within every PKL, suggesting that female students may be more adept at completing faded worked-examples. Students from School A also outperformed those in School B within each PKL, confirming the notion by Reddy et al. (2016) that students of a higher SES generally perform better than those of a lower SES. The performance levels increased as one moved from a low PKL to a high PKL, which was expected. Furthermore, there was a decrease in the gender gap for School B, highlighting that as PKLs increase, male students may become more able to complete faded worked-examples; alternatively, females may become less able to do so. This suggests that low PKL female students, especially those of a low SES, may benefit more from the use of faded worked-examples than males. To provide further insight into this, an analysis of student performances within *each* worked-example in Stage 4 is detailed below.

Tables 4a and 4b show the average performance in each faded worked-example of students from School A and Tables 5a and 5b from School B. As previously stated, worked-example 1 was omitted from the analysis.

		PKL1	PKL2	PKL3	AVG
Worked-example	1	100%	100%	100%	100%
	2	43%	89%	80%	76%
	3	71%	56%	64%	63%
	4	57%	89%	76%	76%
	5	43%	44%	76%	63%
	6	29%	44%	72%	59%
	7	86%	89%	84%	85%
	8	14%	22%	68%	49%

Table 4a: Male Stage 4 Performance - School A

		PKL1	PKL2	PKL3	AVG
Worked-example	1	100%	100%	100%	100%
	2	33%	39%	50%	38%
	3	44%	48%	75%	53%
	4	33%	74%	75%	65%
	5	56%	35%	63%	45%
	6	33%	78%	88%	65%
	7	56%	74%	75%	68%
	8	44%	30%	43%	33%

Table 5a: Male Stage 4 Performance – School B

		PKL1	PKL2	PKL3	AVG
Worked-example	1	100%	100%	100%	100%
	2	50%	50%	75%	57%
	3	59%	33%	75%	55%
	4	82%	72%	94%	82%
	5	45%	67%	69%	59%
	6	64%	72%	81%	71%
	7	73%	72%	94%	79%
	8	36%	67%	81%	59%

Table 4b: Female Stage 4 Performance - School A

		PKL1	PKL2	PKL3	AVG
Worked-example	1	100%	100%	100%	100%
	2	38%	31%	70%	43%
	3	62%	75%	40%	59%
	4	62%	81%	70%	76%
	5	46%	63%	80%	62%
	6	69%	69%	100%	78%
	7	69%	75%	100%	81%
	8	42%	38%	50%	39%

Table 5b: Female Stage 4 Performance - School B

From these results, it was evident that most students performed best in worked-example 7 (WE7). As the answer and backward faded steps were included in this example, students may have been more confident in their approach as they could check their calculations. However, WE5 also included the correct answer but did not display the same high scores as WE7. The major difference between these two examples being that the backwards faded steps provided throughout WE7 were only partly included in WE5. This may have created confusion about how to complete the example, causing student accuracy levels to drop. These results suggest that when faded worked-examples include an answer, student completion and accuracy rates may be improved, but only when the worked-example includes backwards faded steps throughout the question. This supports the results of Reisslein et al. (2007) who report that students in a backwards faded condition outperformed those in the

forward faded condition. However, answers were not provided within the faded worked-examples by Reisslein et al. (2007); thus, caution must be taken in support of this work.

On average, all students, except for females from School A, performed most poorly in WE8 – the problem-solving condition. When considering APOS theory (Asiala et al., 1996), it is possible that these students have not yet progressed enough in their mathematical understanding, and developed appropriate schemas, to solve this example correctly. When compared to other examples, WE8 could be seen to have had a high level of element interactivity, which is indicative of a high ICL (Ngu, Chung, & Yeung, 2015). These elevated levels may explain why most students did not correctly solve this example, as high intrinsic loads have previously been shown to impede learning and performance (Sweller & Chandler, 1994). However, female students from School A had high completion rates in WE8, relative to their male counterparts. This contradicts the meta-analysis data by Hyde and McKinley (2012) who found that males outperform females in problem-solving conditions. This same trend is evident in School B as seen in Tables 5a and 5b, suggesting that female students may be more adept at problem-solving after faded worked-example completion in algebraic fractions. However, female students of a high SES appear to benefit more than their low SES counterparts in this regard. These results suggest that worked-examples may benefit high prior knowledge students, as opposed to only those of low prior knowledge as originally stated within the large body of worked-example research (for examples, see: Cooper & Sweller, 1987; Moreno, 2006; Sweller & Cooper, 1985), and this may be especially relevant to female students.

In looking at average performance rates for PKL3 students, School A males and School B females scored most poorly in WE3. This indicates that the expertise-reversal effect (Kalyuga et al., 1998) may have occurred in these instances, as this example contained faded explanations within the faded worked-examples. Thus, an extraneous load may have resulted

due to the maintenance of irrelevant pieces of information in the students working memory (Schnotz & Kürschner, 2007). The redundancy effect (Sweller, 2005) may have also been present, due to students being required to complete the faded explanations. This highlights that, for high PKL students, incomplete instructional explanations may need to be omitted from faded worked-examples as they could cause an excessive extraneous load and impede learning.

When analysing differences in overall gender performance rates, female students from School A outperformed their male counterparts in only three out of the eight worked-examples (WE4, WE6 and WE8). In School B, female students outperformed males in all the worked-examples, suggesting that female students of a low SES are more able to complete faded worked-examples when compared to males of a similar SES. This suggests that the use of faded worked-examples may allow for a greater allocation of working memory resources to GCL for female students, thus, allowing for improved learning gains (Leppink, 2017). These noticeable differences in performance between genders suggests that faded worked-examples may assist female students of a low SES in South Africa in improving their mathematical understanding, and also support Bevilacqua's (2017) proposal to include gender differences within CLT.

As cognitive load measurements have been linked with the difficulty level of materials, student self-reported difficulty ratings may indicate which examples caused the highest level of cognitive load. As a result, average difficulty ratings were also analysed to further explore this research question. Tables 6 and 7 show the average, student self-reported difficulty ratings of each worked-example from School A and B respectively.

		PKL1	PKL2	PKL3	AVG
Worked-example	1	1.6	1.6	1.2	1.3
	2	4.1	2.7	2.4	2.7
	3	3.7	2.4	3.5	3.3
	4	4.3	2.9	2.2	2.7
	5	5.0	3.0	3.1	3.4
	6	4.7	3.6	3.4	3.6
	7	2.9	2.4	2.4	2.5
	8	5.7	4.9	3.6	4.2

Table 6a: Male Difficulty Rating of Examples in Stage 4 – School A

		PKL1	PKL2	PKL3	AVG
Worked-example	1	2.1	2.0	1.4	1.8
	2	4.5	3.9	3.7	3.9
	3	4.8	3.8	4.2	4.1
	4	3.6	3.4	3.2	3.4
	5	6.1	4.4	5.0	5.0
	6	5.8	4.3	3.8	4.7
	7	4.4	3.8	3.3	3.9
	8	5.6	5.4	5.4	5.6

Table 7a: Male Difficulty Rating of Examples in Stage 4 – School B

		PKL1	PKL2	PKL3	AVG
Worked-example	1	1.6	1.6	1.5	1.6
	2	3.5	2.9	2.5	3.0
	3	3.5	3.6	2.9	3.3
	4	3.1	2.8	2.4	2.8
	5	4.6	3.8	3.4	4.0
	6	4.1	3.6	3.0	3.6
	7	3.6	2.4	1.9	2.8
	8	5.6	4.6	3.4	4.6

Table 6b: Female Difficulty Rating of Examples in Stage 4 – School A

		PKL1	PKL2	PKL3	AVG
Worked-example	1	2.2	1.5	1.2	1.6
	2	5.2	4.7	2.2	4.1
	3	5.3	4.3	2.1	4.0
	4	4.6	3.3	2.1	3.3
	5	4.7	3.9	4.2	4.2
	6	3.9	3.3	2.2	3.2
	7	3.9	2.8	2.9	3.1
	8	5.7	4.6	4.7	4.9

Table 7b: Female Difficulty Rating of Examples in Stage 4 – School B

From the results shown in Tables 6 and 7b, all students from School A and females from School B rated WE7 as having the lowest level of difficulty. This relates well to the results presented in Tables 4 and 5 with WE7 receiving the highest average score, apart from School A females where this was their second highest score. As this backwards faded worked-example included a multi-operation simplification, the ICL can be seen to be high; however, the faded solution steps may have also enabled a reduction in ECL. Although this is difficult to confirm, these results suggest that students perform well when the least amount of ECL is imposed, whilst also regulating the ICL as suggested by Mayer and Moreno (2010). The presence of the answer in this example may have also allowed students to feel more confident. This is confirmed by a PKL2 female student from School A, who stated: “This example helped because if I started getting confused I could check the final answer and solve the problem until I got the same answer as the answer they wrote down.” As a result, backwards faded worked-examples may prove to be more beneficial when there is an answer

included. However, this has not been documented within faded worked-example research and provides scope for expansion in this area.

In accordance with Tables 4 and 5, all students rated WE8 as the most difficult. This is also the example they performed most poorly in, with exception of females in School A. The cause of this high cognitive load may be due to WE8 not including any faded steps. As a result, students had to adopt a means-end analysis approach which has been shown to cause high extraneous and intrinsic loads on working memory (Paas et al., 2004; Reisslein et al., 2007; Sweller, 1988). To provide further clarity on this, students were asked to indicate why they found a specific worked-example difficult; however, only 37% of students from School A and 27% of students from School B completed this section and, as a result, no conclusive evidence could be drawn. This aligns with the position of Leppink and van Merriënboer (2015) and Kantowitz (1987), who noted that attaining accurate measurements of cognitive load often proves to be problematic.

Students from a low SES (School B) also report larger difficulty ratings than their high SES counterparts, with low SES males reporting the highest difficulty ratings overall. Additionally, as one moves from PKL1 to PKL3 difficulty ratings generally decreased. This suggests that students of low prior knowledge and those from a low SES may find new instructional strategies, such as faded worked-examples, difficult to complete, highlighting that teacher assistance may be needed during faded worked-example completion. Additionally, greater teacher assistance may also be needed at the beginning of the intervention to ensure students understand how to complete the examples. This expands on the work by Chi et al. (1989) and Zhu and Simon (1987) who found that students who can effectively self-explain worked-examples do not need the assistance of a tutor or teacher. However, the authors did not distinguish between students of differing prior knowledge or SES in their suggestion. Thus, results from this study allude to possible limitations on this statement, based on a

student's levels of prior knowledge and SES. However, Chi et al. (1989) also posit that students must be actively engaged with the example to learn effectively from it; thus, as the level of engagement with the examples was not recorded in this study, conclusions regarding this notion cannot be made.

On average, males in School A rated the faded worked-examples as less difficult than their female counterparts. This may be due to males having higher PKLs than females, as indicated by the PKL distributions in Table 3. However, in comparing Tables 7a and 7b, low SES female students portrayed much lower difficulty ratings than their male colleagues. As difficulty levels were indicative of high levels of cognitive load, low SES female students may be experiencing lower intrinsic and extraneous loads in the completion of faded worked-examples when compared to their male counterparts. As high cognitive loads have been linked to underperformance in mathematics (Carroll, 1994; Rentowati et al., 2017; Sweller & Cooper, 1985; Zhu & Simon, 1987), where students experienced a high cognitive load, learning may thus have been negatively affected. As a result, it is important to analyse student performance in Stage 5 to determine if their learning had indeed been affected.

4.2 Research Question 2

How does the use of faded worked-examples affect students' ability to simplify algebraic fractions?

Figures 11 and 12 show the association between Stage 1 and Stage 5 results for School A and B, respectively, with Table 8 showing the correlations between these stages for male and female students. No outliers were found in the data for Figures 11 and 12.

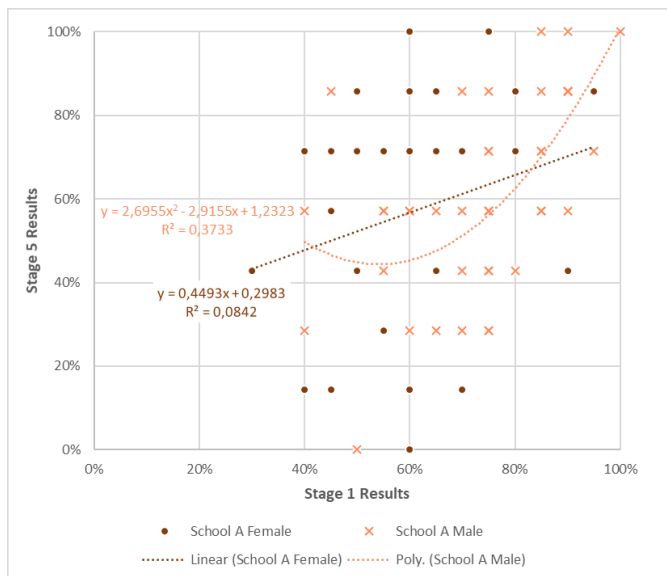


Figure 11: Stage 1 vs Stage 5 Results – School A

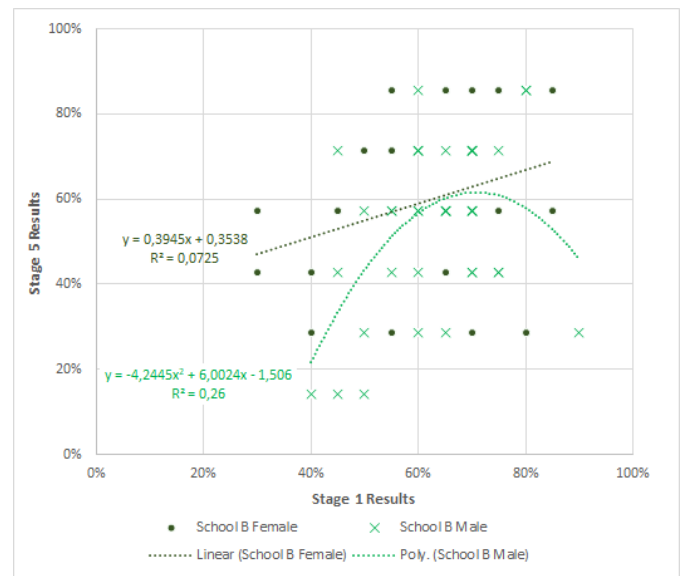


Figure 12: Stage 1 vs Stage 5 Results – School B

	SCHOOL A	SCHOOL B
FEMALE	0.290	0.269
MALE	0.534	0.375

Table 8: Correlations between Stage 1 and Stage 5

Results from Table 8 indicate positive correlations between Stage 1 and Stage 5 for both male and female students. However, upon further differentiation of these correlations according to PKL, an interesting trend emerged for male students in both schools. These results are shown in Table 9 and 10 for School A and B respectively.

SCHOOL A	PKL1	PKL2	PKL3
FEMALE	0.07	-0.11	0.10
MALE	-0.03	0.16	0.64

Table 9: Correlation of Stage 1 vs Stage 5 Results – School A

SCHOOL B	PKL1	PKL2	PKL3
FEMALE	0.26	0.17	-0.07
MALE	0.41	0.02	-0.28

Table 10: Correlation of Stage 1 vs Stage 5 Results – School B

PKL1 males from School A exhibited a slightly negative correlation between Stage 1 and 5 and this value increased to 0.64 for PKL3 males. This suggests that males within the different PKLs are differentially affected by faded worked-examples with PKL1 males being more disadvantaged than their peers of higher prior knowledge. These results are evident in Figure 11, where School A males exhibit a positive parabolic association between Stage 1 and Stage 5. This indicates that as PKL1 male scores in Stage 1 increased from 40% to 54%, their corresponding Stage 5 results decreased. However, males who scored the lowest results in Stage 1, scored higher relative results in Stage 5, indicating that positive learning gains may have been experienced as a result of completing faded worked-examples for these very low achieving male students – this further verifies that worked-examples benefit students of low prior knowledge (Cooper & Sweller, 1987; Spanjers et al., 2012; Sweller & Cooper, 1985). Despite the positive trend for PKL2 and PKL3 males, these students still achieved lower Stage 5 results, relative to Stage 1. Thus, faded worked-examples may only improve learning for high SES male students with very low PKLs. These results further highlight the need for a rigid classification system of student PKLs, as originally suggested by Reisslein et al. (2007).

From Table 10, PKL1 males from School B exhibit a positive correlation that decreased to -0.28 for PKL3 males. This decrease in correlation as one moves from PKL1 to PKL3 is opposite to that seen in School A. The negative parabolic association between Stage 1 and Stage 5 for low SES male students, as displayed in Figure 12, is indicative of these changing correlations. These results indicate that low SES male students of a moderate to high PKL may be more disadvantaged in comparison with their low PKL peers, indicating the possible presence of the expertise reversal effect (Kalyuga, 2007; Kalyuga et al., 2003). Results from Table 10 also show that as PKLs increased, correlations decreased for both males and females of a low SES, suggesting that student performances in Stage 5 deviate more from

those in Stage 1. This further indicates that the expertise reversal effect may be more prevalent in low SES students, as these trends were not evident in the results of School A.

In Figure 11, School A females displayed a moderately positive, linear trend between Stage 1 and Stage 5. However, as seen in Table 9, there is a very weak correlation within the different PKLs for these students, indicating that performance in Stage 1 was not associated with that in Stage 5. However, in analysing the linear association for School A females in Figure 11, those who achieved between 30% and 50% in Stage 1, improved their relative performances in Stage 5. In comparison, female students who achieved over 50% in Stage 1 did not achieve a greater relative performance in Stage 5. These results indicate that very low achieving females from a high SES may experience an advantageous gain in learning from the use of faded worked-examples, when compared to other females of the same SES. These results are similar to those of low PKL, high SES, male students, indicating that faded worked-examples may indeed benefit both male and female students of very low prior knowledge.

When compared to School A, results from Figure 12 show a slightly lower positive, linear association for School B females. However, PKL1 females from School B displayed a larger positive correlation in results between Stage 1 and Stage 5, when compared to their School A counterparts, suggesting that Stage 1 performances were more predictive of that in Stage 5 within this category. However, in analysing this association in Figure 12, female students in School B who scored lower than 60% in Stage 1 received higher relative results in Stage 5. Analogous to School A females, these results suggest that, as a result of engaging with faded worked-examples, female students of low prior knowledge experience greater learning gains than other females of the same SES – results that are in accordance with previous worked-example research (Atkinson et al., 2000; Cooper & Sweller, 1987; Sweller & Cooper, 1985).

Altogether, these results suggest that female learning of algebraic fractions may not be negatively affected by the use of faded worked-examples, but male learning may be

differentially affected according to PKL and SES. However, due to the varied student numbers within each PKL, conclusive results should be drawn with caution. To provide a more in-depth analysis, both the overall student performance in Stage 5 (see Figure 13a and 14a), and their performance in each question of this stage (see Figure 13b and 14b), will henceforth be analysed. Student performances in each question according to PKL can be seen in Appendix 7 (page 167). Student performance for Question 1 is omitted from the analysis as it did not include elements from both fractions and algebra.

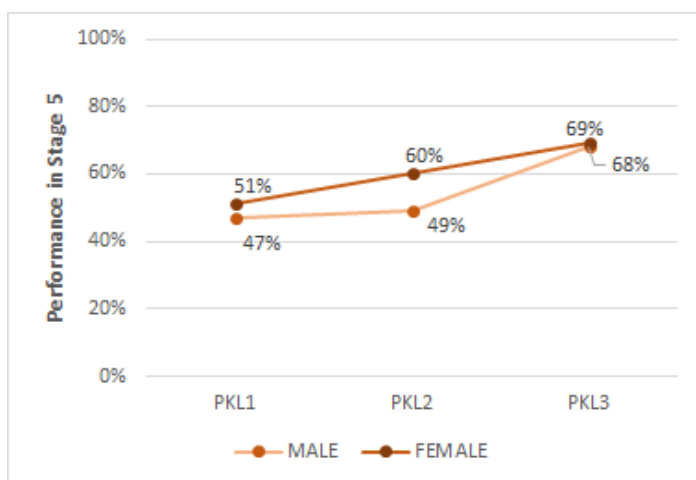


Figure 13a: Average performance in Stage 5 – School A

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
AVG	93%	69%	69%	70%	44%	37%	35%
STDEV	25%	46%	46%	46%	50%	48%	48%
MALE	95%	68%	76%	66%	37%	37%	44%
STDEV	16%	10%	30%	27%	25%	18%	20%
FEMALE	92%	70%	65%	73%	49%	37%	29%
STDEV	10%	9%	4%	8%	11%	24%	23%

Figure 13b: Average performance and standard deviation for questions in Stage 5 – School A

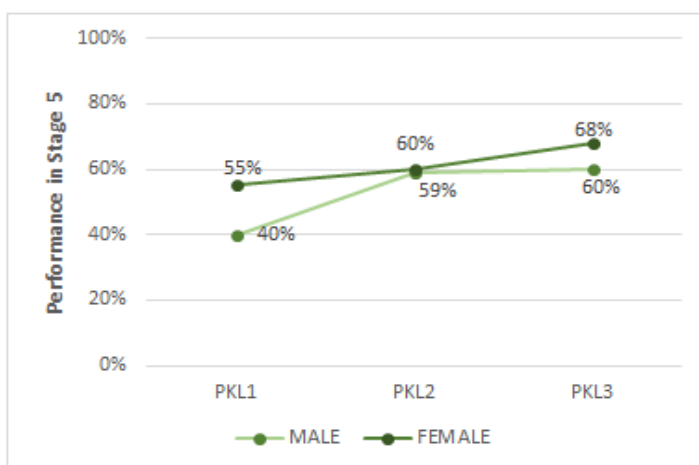


Figure 14a: Average performance in Stage 5 – School B

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
AVG	98%	60%	60%	47%	81%	52%	0%
STDEV	3%	17%	15%	19%	11%	14%	0%
MALE	98%	60%	60%	38%	79%	48%	0%
STDEV	2%	23%	14%	16%	14%	18%	0%
FEMALE	98%	62%	66%	55%	85%	55%	0%
STDEV	4%	11%	14%	20%	6%	10%	0%

Figure 14b: Average performance and standard deviation for questions in Stage 5 – School B

Overall Stage 5 results, shown in Figure 13a and 14a, increase as one moves from a low prior knowledge (PKL1) to a high prior knowledge (PKL3). From the results, it appears that

students are able to simplify algebraic fractions, with female students outperforming males at all PKLs from both high and low socioeconomic backgrounds. This indicates that female students may be learning more effectively through the completion of faded worked-examples, but the reasons for this are not known. However, these gender differences may support the notion that male and female students process materials differently (Geary, 2008). These results also show that, at high PKLs, female students outperform males, which contrasts the results of PISA 2012 (OECD, 2013). Thus, faded worked-examples may assist in minimising the gender differences seen in mathematics performance at high PKLs. However, as no African country was included in PISA 2012, it may prove difficult to compare the results of these two studies.

Of particular interest are the results for Question 5 (Q5) shown in Figures 14a and 14b. After consulting with the HOD from School A, Q5 was included in this stage to assess if students could apply their knowledge to unfamiliar questions (far transfer). Within Stage 4, students only worked on simplifying algebraic fractions with numerical denominators, whereas in this question, the denominators consisted of two variables: x and y . Within School A, male students performed the worst in this question with only 37% attaining the correct answer. However, 12% more female students could solve this question with a lower standard deviation of 11% between the PKLs. This indicates that, not only are high SES female students better able to solve far transfer questions than males, but there is also less variation in their ability to solve these within the different PKLs. Importantly, when looking at Figure 14b, students of a low SES greatly outperformed their high SES counterparts in Q5, with female students outperforming males by a smaller margin of 6%. Interestingly, the standard deviations for School B were also much lower than those of School A, indicating smaller variations within the PKLs, supporting the research by Renkl and Atkinson (2003) who found that self-explanations and backwards faded worked-examples foster far transfer. However, it also

expands on this by showing this effect to be more beneficial for female students and those of a low SES.

When looking at performance in Q5 within the different PKLs for School B, low prior knowledge students performed well, with males attaining 60% and females 93%. These results confirm the notion that worked-examples assist low prior knowledge students in the initial stages of knowledge acquisition (Sweller, 1988; Sweller & Cooper, 1985; Tarmizi & Sweller, 1988; van Gog, Kester, & Paas, 2011). Additionally, they also appear to assist low SES students of all prior knowledge levels, especially females. However, caution must be taken when inferring that faded worked-examples assist all levels of low SES students, as the extent to which students may have received assistance from their teachers and/or peers is unknown. As a result, additional measures may need to be taken in future to ensure students complete these tasks individually.

When analysing PKL1 students from School A (see Appendix 7 page 167), males attained 0% for Q5 and females 46% which is far below their PKL1 counterparts in School B. As PKL1 students have the lowest level of prior knowledge, their performance in Q5 indicates that they may have not acquired a sufficient level of mathematical understanding to achieve far transfer success (Atkinson et al., 2003). Within the scope of APOS theory, these students may have underdeveloped schemas in this area, thus making far transfer and problem-solving an inordinately difficult task for them (Asiala et al., 1996). This is confirmed by their poor performance in Q7, the problem-solving condition, which will be discussed next.

When looking at results for Q7 from School B, no student attained the correct answer, providing a stark contrast to their high performance in Q5. These results suggest that although low SES students can apply their knowledge of algebraic fractions to far transfer questions, it may not have matured enough to successfully answer problem-solving questions. However,

Q7 required a firm understanding of English, which 94% of School B students indicated is not their home language (see Appendix 8 page 168) - which may also account for their null performance in this question. As a result, the factors affecting the performance of School B students in Q7 are questionable.

Despite this, the performances for School A and B, although considerably low for some students, show promise for the use of faded worked-examples in the classroom. This is in accordance with results from previous research on the use of worked-examples (Bokosmaty et al., 2015; Hesser & Gregory, 2015; Sweller & Cooper, 1985; Zhu & Simon, 1987). However, it also extends this research by indicating that the use of faded worked-examples may further enhance learning for female students and those of a low SES. These results contradict the findings of Kaufman (2007) and Lynn and Irwing (2008) who found that males possess greater mathematical working memory capabilities. Thus, as worked-examples are thought to decrease cognitive load (Sweller & Cooper, 1985) and female students outperformed males at all levels in this study, faded worked-examples may enable an improvement in mathematical working memory capacity for female students. As female students have frequently outperformed males, an important ethical consideration of whether or not male students have been negatively affected by the use of faded worked-examples in this study, should be taken into account, as this has not been documented previously in literature. Additionally, as language proficiency has been linked to mathematics performance (Akbasli et al., 2016; Howie, 2003), the students' home language may be affecting the differences seen in SES. However, this was not analysed in this project and provides an interesting area for further exploration.

4.3 Research Question 3

How do students perceive the use of faded worked-examples in the classroom?

Figures 15a and 15b respectively show the percentage of students in each PKL from School A and B who believed faded worked-examples helped them learn how to simplify algebraic fractions.

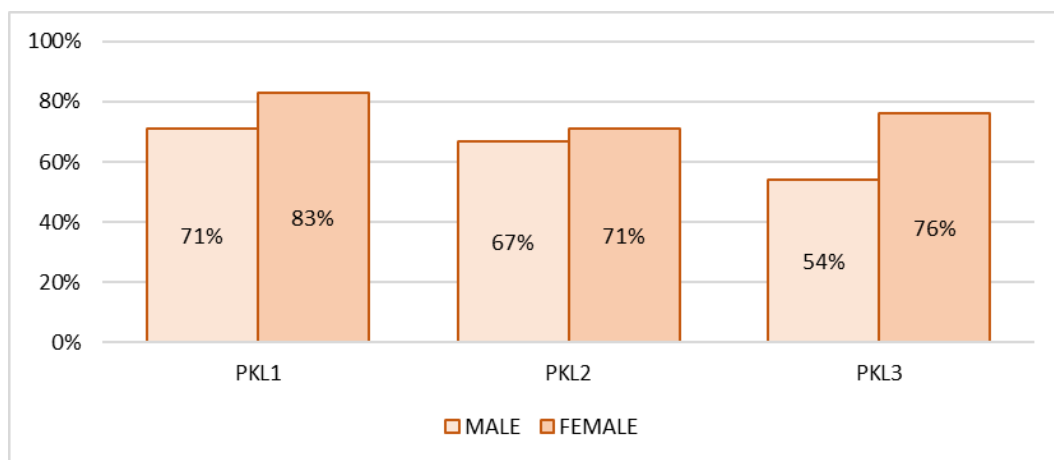


Figure 15a: Percentage of students who found worked-examples helped them learn how to simplify algebraic fractions – School A

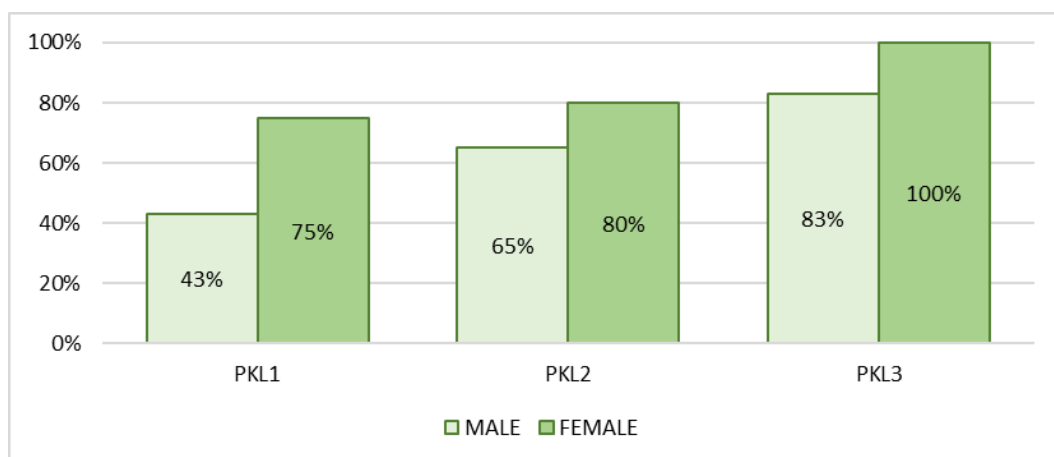


Figure 15b: Percentage of students who found worked-examples helped them learn how to simplify algebraic fractions – School B

Although perception data within worked-example research is limited, it has been stated that the “attitudes of... low and medium prior knowledge participants [are] significantly more

positive” towards the usefulness of worked-examples for their learning (Reisslein et al., 2007:53). However, results from Figures 15a and 15b indicate that over 60% of students in each category found faded worked-examples beneficial for their learning, except PKL3 males of School A and PKL1 males of School B with only 54% and 43% of these students indicating so. As documented by Kalyuga (2007), PKL3 male students may already possess well-developed schemas in algebraic fractions; thus, these students may become bored, frustrated and even confused in completing faded worked-examples. However, this analogy cannot be applied to PKL1 male students from School B, as they were shown not to have well-developed schemas in fractions or algebra in Stage 1. Building on this, as the language of instruction and home language have been shown to be significant factors affecting mathematics performance in South Africa (Howie, 2003), PKL1 males may not find faded worked-examples beneficial to their learning as the instructions throughout the intervention were in English. As females have also outperformed males in reading ability (Van Broekhuizen & Spaull, 2017), this may also account for why males are more disadvantaged in this regard than females. In line with this, during the interview a PKL1 male student from School B stated: “I like to have my teacher explain cause I don’t like to read the math” *[sic]*. Similarly, a PKL2 male student from School B also indicated that he did not like the faded worked-example approach and when probed as to why, he responded, “Because I don’t fully understand other language words and I get stuck” *[sic]*. This provides some important insight into the potential reasons why worked-examples may not benefit students from a low socioeconomic background, who also struggle to read and write in English.

Although the use of faded worked-examples has allowed for improved learning gains for low prior knowledge students (Spanjers et al., 2012; Sweller, 2006; Sweller & Cooper, 1985), high prior knowledge students also indicated the positive effect of faded worked-examples on their learning, with 100% of high prior knowledge (PKL3) female students from School B indicating

that faded worked-examples helped them learn how to solve algebraic fractions. This is epitomised by a PKL3 female from School B, who stated: “It [worked-examples] made me completing the questions quite easy and the worked-examples points or gives me a direction in which I can follow” *[sic]*. During the interview, another PKL3 female student also stated, “[t]here were things that I wasn’t know how to do but now I know. I know, and I’ve learned the best on algebraic fractions” *[sic]*. Similarly, 76% of PKL3 females in School A also indicated that faded worked-examples helped them learn, with one student stating, “I find it easier to learn when part of the learning is filling in the missing numbers or words.” However, there were several comments that indicated the worked-examples were unnecessary and sometimes caused confusion for high PKL students. These can be seen in the comments below from three other PKL3 students from School A:

“I work better when just given the question, answer and a set of steps to start off. I don’t really like filling in values on worked-examples. I can’t work with a good flow.” (Female-1)

“It made me confused about what I had done before.” (Male-1)

“I already understood algebra – it was not really helpful, just extra work.” (Male-2)

This emphasises that faded worked-examples may inhibit learning when students already have well developed schemas – a notion already well-documented and encompassed by the expertise reversal effect (Kalyuga, 2007; Kalyuga et al., 2003). However, it is unknown what factors caused some of the higher prior knowledge students to perceive faded worked-examples to be useful, and others not.

Compared to males, more female students indicated that faded worked-examples helped them learn how to simplify algebraic fractions. This was not confined to a PKL or school, indicating that, in general, female students in this study found faded worked-examples to be more useful for their learning than male students. Although no research could be found to

support or critique this, gender differences have only recently been considered within CLT (Bevilacqua, 2017), and this area of research may still be developing. Additionally, the factors that cause female students to express a greater perception of the effectiveness of faded worked-examples, compared to males, is also not known. However, from observations of my students, females tend to take a more calculated approach, trying to minimise the initial amount of errors they make, whereas males tend to take more risks, initially making more mistakes, but correcting these as they go. This is especially epitomised by one of my female students who did not want to make a mistake in her book because she did not want to “cross it out” (Female, PKL2, Pilot Study). In analysing the steps of a faded worked-example, female students may feel more confident that they will not make a mistake, and this may be why they feel they can learn from them. This provides an interesting area for future research as, if female students can feel more confident in their approach through the use of faded worked-examples, they may experience greater learning gains as a result.

Referring to Figures 15a and 15b, more students from School B perceived faded worked-examples to assist in their learning of algebraic fractions, when compared to their colleagues in School A. However, this is not true for PKL1 students, where more School A students found that worked-examples helped in their learning when compared to PKL1 students in School B. There could be many reasons for this; however, from personal experience, levels of mathematical competition in School A may be notably higher than those within School B. Thus, School A students may view the use of faded worked-examples as a tool to ‘catch up’ to their high-achieving peers. In further analysing the commentaries, faded worked-examples may initiate the recall of previous schema for low prior knowledge students, as a PKL1 female from School B states, “They helped [me] understand and to remember other examples I once given before” [*sic*]. In addition to this, a PKL1 male student from School A also stated that the faded worked-examples “helped jog my memory a bit”. These comments indicate that faded

worked-examples may decrease the load on working-memory by activating cognitive recall. In doing so, this may allow for efficient reorganisation of mental schema (Sweller, 2010) and improved learning.

Additionally, students may also value the use of faded worked-examples more if their use allowed for the identification of prior misconceptions, as this may have allowed for the repair of existing, faulty schemas. However, when analysing Figure 16b, 71% of PKL1 male students indicated that they were able to identify prior misconceptions but only 43% found faded worked-examples helped them learn how to simplify algebraic fractions.

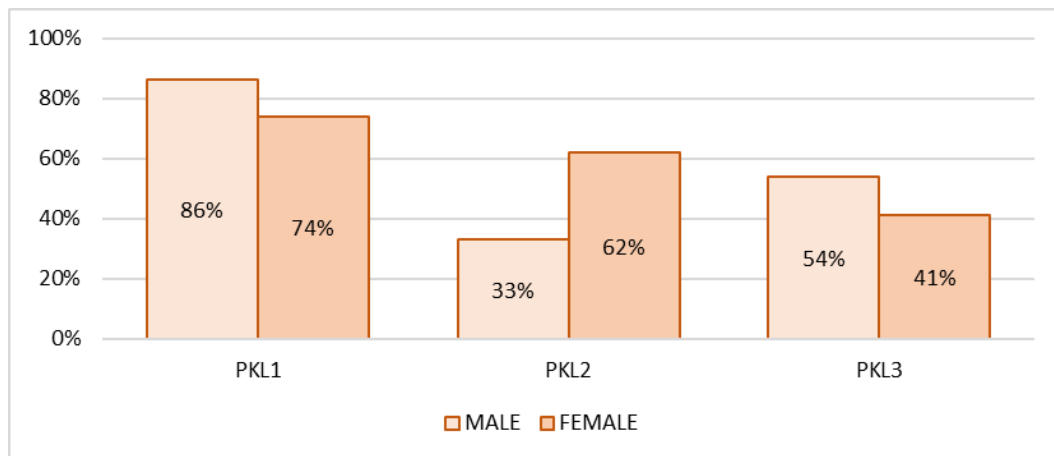


Figure 16a: Percentage of students who indicated that WEs helped them to identify prior misconceptions - School A

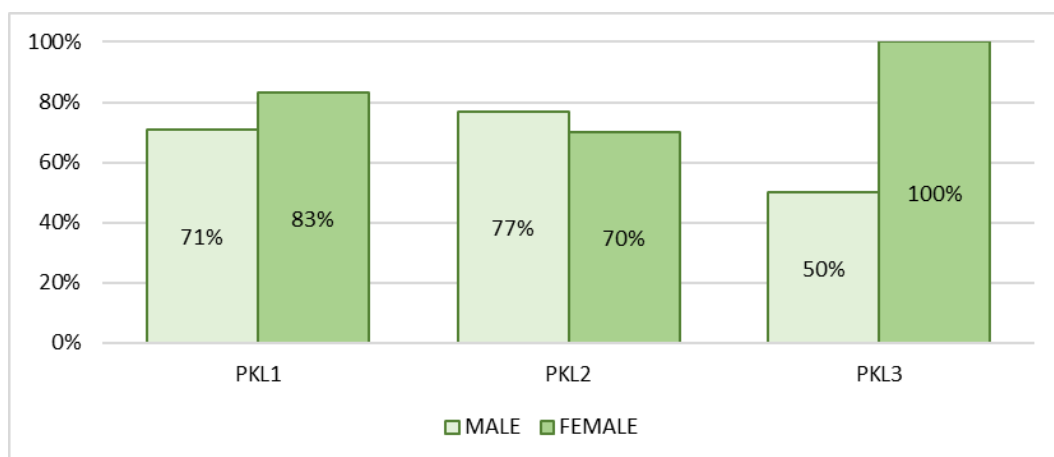


Figure 16b: Percentage of students who indicated that WEs helped them to identify prior misconceptions - School B

Consequently, these students may not find faded worked-examples beneficial for their learning as, in identifying their misconceptions, their confidence in mathematics may have been eroded. Future studies should carefully consider this factor as the use of faded worked-examples for these male students may pose ethical problems with regards to decreased self-efficacy perceptions.

Overall, the results in Figures 16a and 16b suggest that most students were able to identify their prior misconceptions by using faded worked-examples. This provides an interesting counterargument to Richey and Nokes-Malach (2014) who could not find sufficient evidence that worked-examples corrected misconceptions. However, it is unknown whether the students in this study corrected their misconceptions upon identifying them, and a follow up survey question should be used in the future to determine this.

In comparing the results from Figure 16a and 16b, students from School B generally indicate a much higher perception of misconception identification than students from School A, except for PKL1 and PKL3 males. This may be a product of the large class sizes of School B, in which students potentially receive little individual attention from the teacher. In this case, faded worked-examples may be providing this assistance in a different form to the students, thus allowing them to correct their misconceptions. This is in accordance with research that posits that, through the use of worked-examples, students are able to learn without the presence of a teacher or tutor (Chi et al., 1989; Zhu & Simon, 1987). This has great implications for mathematics classrooms in impoverished South African areas, where student numbers often exceed fifty per class (Reddy et al., 2016). However, caution must be taken in this statement as class size was not found to be indicative of mathematics performance in the TIMSS-R analysis by Howie (2003). Despite this, the TIMSS-R data did not differentiate between class size and the amount of time a teacher spent assisting each student within their class. Thus, as class size may impede the ability of a teacher to assist each student

individually, the use of faded worked-examples may still show promise in improving understanding where class sizes are large.

Previous research states that this instructional strategy is only beneficial for students at the initial stages of knowledge acquisition (Cooper & Sweller, 1987; Sweller & Cooper, 1985). However, this was in relation to a student's performance in isomorphic questions and did not take into consideration their perceptions on the strategy. Perception results in Figures 16a and 16b indicate that faded worked-examples improve learning of both low and high prior knowledge students, which contrasts with prior worked-example research. As the identification of misconceptions has been shown to be vital for sound mathematics performance (Booth & Koedinger, 2008; Resnick et al., 1989), if faded worked-examples can assist in the identification of these, then their use may be beneficial to students of all levels of prior knowledge. However, the identification of misconceptions, and the associated modification of existing schema, takes place slowly – as is posited by the narrow limits of change principle (Sweller et al., 2011); thus, improved performance in an immediate post-test may not be found. As a result, future studies should include a delayed post-test to allow for the changes within a schema to occur.

Student commentary data also provided further insight into their misconceptions and perceptions on using faded worked-examples with a PKL2 male student from School B, stating, "I was confused I did not know what to do and the example helped me with my problems." This suggests that faded worked-examples may have provided the procedural information needed to complete the problem, but they also may have corrected a prior misconception, which then enabled the student to understand the procedure being used. Similarly, a PKL3 female from School A also stated, "They [worked-examples] helped me in knowing where I went wrong" and a PKL1 female student from School A stated, "I forgot how

to do fractions and I never really understood them but when I saw the examples and instructions it helped me a lot to remember and learn it.”

Overall, the use of faded worked-examples shows potential to assist students in identifying prior misconceptions. However, it may not be as beneficial for middle to high PKL students from a high SES as only 33% of PKL2 male and 41% PKL3 female students from School A (Figure 16a) indicate that faded worked-examples helped them to identify their misconceptions. This further alludes to the possible presence of the expertise reversal effect (Kalyuga, 2007), which may also account for the differences seen between Figures 17a and 17b, with more students from a low SES (School B) indicating they would like faded worked-examples to be used again.

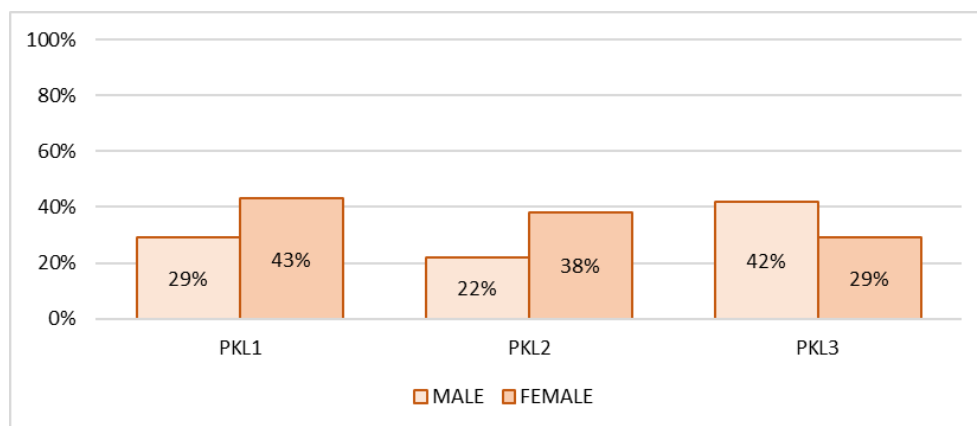


Figure 17a: Percentage of students from School A who would like WEs to be used again in class



Figure 17b: Percentage of students from School B who would like WEs to be used again in class

To account for these differences, student commentaries were further analysed and in response to my question on if they wanted faded worked-examples to be used in the future, a PKL2 male student from School B answered, “Yes because when you completed examples it makes to understand about mathematics and make feel like you know how to learn mathematics” *[sic]*. Additionally, a different PKL2 male student from School B stated: “They [the worked-examples] have helped me a lot and I can do at home” *[sic]*, alluding to the possibility that he now feels comfortable to learn on his own. These commentaries highlight the fact that low SES students are finding the use of faded worked-examples valuable for their learning. This contrasts with School A, where less than 43% of all students displayed a desire for their future use. This data is contradictory as, although some students found value in the use of faded worked-examples for their learning, most did not want them to be used again in class. This may be due to the length of the intervention, as Reisslein et al. (2007) found that high prior knowledge students prefer a shorter faded worked-example approach. However, this condition may also suit students from a high SES and those situated in small classes, as this would enable the teacher to assist these students more readily than if they were part of a large class, thus, negating the need for a faded worked-example to provide this guidance. Conversely, students of a low SES, who experience low rates of individual teacher contact time, may find this approach valuable as it provides them with a greater amount of information from which to learn. Results by Chi et al. (1989) support this claim as they found that worked-examples have the potential to teach students without the support of a more knowledgeable other.

5. Conclusion

5.1 Summary of findings

Research Question 1:

Students were able to complete faded worked-examples, with females displaying superior completion rates to males in both high and low socioeconomic status schools. All students rated faded worked-examples as having a lower level of difficulty and subsequent cognitive load, with problem-solving-type questions having the highest difficulty ratings and, thus, cognitive load. These results are in-line with current literature. Students from a low socioeconomic status also reported higher levels of cognitive load compared to their higher socioeconomic status counterparts, suggesting that greater teacher assistance may be required to support these students in completing faded worked-examples. Male students of a high socioeconomic status reported lower cognitive load ratings than females when completing faded worked-examples; however, female students of a low socioeconomic status reported lower cognitive loads than males. These results further suggest the presence of gender differences within cognitive load theory, with specific regard to a student's ability to complete faded worked-examples and how difficult they find this task. Furthermore, they also allude to possible cognitive load differences amongst students of different socioeconomic status.

Research Question 2:

Students appear to be differentially affected by the use of faded worked-examples, with female students from both a low and high socioeconomic status exhibiting a moderately positive linear association between Stage 1 and Stage 5 performance. Low prior knowledge female students from Stage 1 performed better in Stage 5, relative to their Stage 1 results, indicating that faded worked-examples may benefit these students most. Low prior knowledge males from a high socioeconomic status and high prior knowledge male students from a low

socioeconomic status appear to be more disadvantaged by the use of faded worked-examples. Consequently, caution needs to be taken to ensure that male students are not significantly disadvantaged by this approach. Female students appear to be able to complete isomorphic questions more readily than males, indicating that females may benefit more from a faded worked-example approach. Students of low prior knowledge can solve isomorphic, but not problem-solving, type questions after the completion of faded worked-examples; thus, greater teacher assistance may be required for these students, especially those of a low socioeconomic status.

Research Question 3:

Most students indicated that faded worked-examples helped them learn how to simplify algebraic fractions, except for high prior knowledge males from School A and low prior knowledge males from School B. The expertise reversal effect was believed to be the cause of these results for high prior knowledge males from School A, and poor literacy rates in low prior knowledge males from School B. However, the ability of students to read and write English was not measured in this study and provides an interesting area of exploration for future research. Additionally, more female students, from both low and high socioeconomic backgrounds, indicated that faded worked-examples helped them learn how to simplify algebraic fractions. The use of faded worked-examples shows potential for improving the learning of students from low socioeconomic backgrounds by affording them the opportunity to identify and correct their prior misconceptions. This may be particularly pronounced for female students of all prior knowledge levels within this category. Most students of low socioeconomic status indicated that they would like faded worked-examples to be used again in the classroom, indicating that students from a low socioeconomic background may find more value in this approach compared to students from a high socioeconomic background.

5.2 Implications for Practice

Within my practice, these results have highlighted that I need to take student gender and socioeconomic background into account when using faded worked-examples. With regards to mathematics support classes, I will be more inclined to use faded worked-examples with my female students. However, with male students, it may be more beneficial to explain a concept verbally to them. For my students from a low socioeconomic background who have poor levels of prior knowledge, I will also be inclined to use this approach with the female students and more cautiously with males.

With regards to practice outside of my own classroom, these results have important implications for teachers who work with students from a low socioeconomic background. Faded worked-examples show promise in improving the understanding of mathematical content through the identification and possible correction of student misconceptions. As a result, the regular incorporation of faded worked-examples into the classroom may prove beneficial for students and especially those who form part of large class. However, the cost of printing the relevant materials is very high and may not be feasible for resource-poor schools. In light of this, the methods of disseminating faded worked-examples in the classroom may need to be reconsidered. For example, instead of each student completing their own set of faded worked-examples, students could work together in larger groups to reduce printing costs. Ultimately, as faded worked-examples show promise for improving mathematical understanding and performance for a diverse range of students, teachers should attempt to introduce them, where possible.

5.3 Evaluation of Collaboration

The collaborative aspect of this project was vital to establish how using faded worked-examples impact on students of different socioeconomic background and gender. As a result, it was important that the collaboration with teachers and their students from other schools be carefully planned and carried out. The coordination of meetings with two different schools proved difficult and highlighted some of the challenges of collaboration. However, collaborating with teachers from School A and B was both efficient and simple as both HODs were open towards, and interested in, new innovations in the teaching landscape.

As many teachers were involved in the administration of the intervention materials, a limitation is noted in that different teachers may disseminate materials differently. This is an area that requires greater control in the future.

Teachers' comments on the process were positive, with a teacher from School A stating,

I think this is a great approach. Students need a framework within which to work. If they are provided with partial steps and asked to complete the final part, I believe this can help all students, but especially the weaker ones.

Upon collection of the results, a School B teacher mentioned that her students were excited about using the examples and appeared to be more engaged in the material which allowed her more time to assist those who did not understand. This teacher also stated that "At the end of the lesson they [the students] suggested that I can bring more lessons like these" *[sic]*. This teacher appeared to be excited about using this approach in class and indicated that she would use it again to help her students. Collaborating with School B also allowed for new connections to be established and future collaborations, both with staff and students, have been planned. Collaborating with School B also made me aware of the need for and importance of sharing knowledge and resources with colleagues from a less advantaged background and those who may not have the same access to current educational knowledge.

5.4 Concluding remarks

Students were able to complete faded worked-examples adequately and apply this knowledge to questions where only the problem-state is posed. However, this varied according to a student's prior knowledge level, gender and socioeconomic status, with results indicating that a faded worked-example approach may favour female students and those of low socioeconomic status – a notion that may be of paramount importance if South Africa is to improve its mathematics performance. Students of a low socioeconomic status also preferred the use of faded worked-examples when compared to those of a higher socioeconomic status, with females showing a greater preference for their use. However, as these outcomes are specific to only a few South African students, they may not be applicable to other students in different educational contexts.

As Slavit, Kennedy, Lean, Nelson, and Deuel (2011:114) state, “[t]eachers who have the ability to truly engage in a collaborative effort to improve student learning... are in a position to transform not only their individual practice, but to transform the culture and practice of a group of teachers... and perhaps even a school.” In collaborating with many different teachers from two vastly different schools, I have not only transformed my own practice, but I have also gained an understanding of the culture and pedagogy of other teachers in different contexts. In working together, teachers and students have the potential to greatly improve understanding of both mathematics and each other and, collectively, this has the potential to create a more fruitful future for South Africa.

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Dear Teachers

Thank you for participating in my research!

Please note that all the information that you or the students provide will be kept strictly confidential and you will not be identified in my report. I will only state "Teacher A stated that..." and "Student A stated that...."

Please may you also reassure the students that I will not print their names anywhere either and their information will be kept strictly confidential.

Thank you again! I hope you find the process over the next 3 lessons worthwhile 😊 If you have any queries please message or whatsapp me

or

Warm regards



[\[Click here to go back to text\]](#)

Notes for Teachers

Thank you for taking the time to fit my research into busy schedule. I have made a few notes for you detailing any possible questions that may arise during the process.

Please document anything you notice in the far-right column or anything you think was “out of the norm”.

If you or your students find any errors in the materials please ask them to just indicate this on their answer sheet.

LESSON 1		
Stage 1	Learner Pre-Assessment • Learners are not allowed any calculators in this stage. Assessment is to be done under test conditions. • Please read the instructions with them and ask them to shade in their multiple choice grid with a pencil. • They are allowed 30-40 minutes for this section. • When they are done, you can take in their answer grid and question paper and administer Stage 2 – the learner pre-intervention survey. • Please ensure their names are on each assessment. • PLEASE COMPLETE THE TEACHER PRE-SURVEY AT THIS STAGE	Notes and observations

Stage 2	Learner Pre-intervention Survey • Learners are to complete this stage individually. • Please assist where required. Some learners may not know what their parents education level is – please help them with trying to establish this if they do not know.	Notes and observations
LESSON 2		
Stage 3	Group work • Please choose the pairs that the learners will work in. You know them best! • Read the instructions with them and make sure they check their answers on the back page as they go. • During this stage you must give them little to no assistance! They need to use the materials and their partner to figure it out. • When the pair of learners is done, you can hand them Stage 4 – the individual work. • Leave Stage 3 on their desks so they may refer back to it should they feel the need to.	Notes and observations

Stage 4	Individual work • Please read the instructions with the learners to ensure they know what to do. • Each worked-example is different and they need to read the instructions on how to complete it. • This stage must be done under test conditions – learners must not receive help from their peers or their teacher. • You may assist the learners with where to write their answers and how to fill out the rating form at the end of each worked-example. • Stronger learners can attempt worked-example 7 and 8. If you see that weaker learners are struggling, tell them to not worry about completing those worked-examples.	Notes and observations
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LESSON 3		
Stage 5	• This is the third and final assessment stage. Learners must complete this stage on their own. They may use calculators if they wish to do so. • Stronger learners will enjoy the last question, however weaker learners may struggle somewhat. • Once you have collected all the papers, please feel free to go over each question with the learners should they ask you to do so. • When all the papers are in you can administer the final Stage 6: the learner post-intervention survey.	Notes and observations
Stage 6	• This is quite short and learners should finish relatively quickly. • Please encourage them to add any comments about the process and materials that they would like to add. • If they enquire about being interviewed, let them know that this will most likely take place in the format of a group interview at the end of the school day. However, if they would prefer an individual interview then this will be perfectly fine! • PLEASE COMPLETE THE TEACHER POST-SURVEY AT THIS STAGE	Notes and observations

THANK YOU SO MUCH FOR ALL YOUR TIME!

I REALLY DO APPRECIATE IT AND WOULD LOVE TO HEAR YOUR THOUGHTS ON THE PROCESS – GOOD OR BAD 😊

Teachers name: _____

My name: _____

Dear Grade 9 students

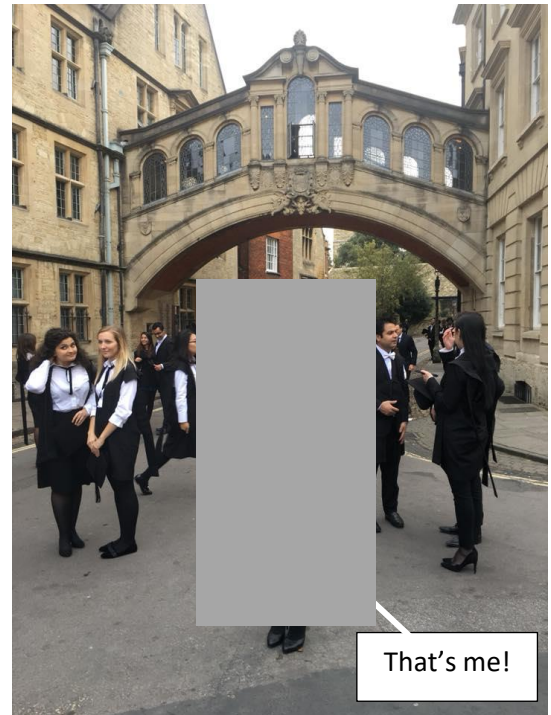
My name is _____ and I am studying Mathematics Education at the University of Oxford.

Your teachers have kindly agreed to participate in my research which consists of 3 stages of assessment and 2 stages of questionnaires.

Two of these stages will be used by your teachers as marks for the term, so please do try your best! Your teachers won't be able to help you in this Stage, so you will need to work on your own and silently.

No calculators are allowed in this Stage and you need to indicate your answer on the grid provided.

Good Luck!!



Instructions:[\[Click here to go back to text\]](#)

1. Answer each of these questions to the best of your ability.
2. There is ONE correct answer for each question.
3. Indicate your answer by shading in your choice on the grid provided.

1. $\frac{4}{100} + \frac{3}{1000}$

- A 0.043
- B 0.1043
- C 0.403
- D 0.43

2. $3\frac{5}{6}$ in decimal form, rounded off to 2 decimal places is:

- A 3.81
- B 3.82
- C 3.83
- D 3.84

3. Which fraction is equivalent to 0.125?

- A $\frac{125}{100}$
- B $\frac{125}{1000}$
- C $\frac{125}{10000}$
- D $\frac{125}{100000}$

4. Which of these number sentences is true?

A $\frac{3}{10}$ of 50 = 50% of 3

B 3% of 50 = 6% of 100

C $50 \div 30 = 30 \div 50$

D $\frac{3}{10} \times 50 = \frac{5}{10} \times 30$

5. Which number is equal to $\frac{3}{5}$?

A 0.8

B 0.6

C 0.53

D 0.35

6. Ann and Jenny divide R560 between them. If Jenny gets $\frac{3}{8}$ of the money, how much money does Ann get?

A R210

B R1493.33

C R350

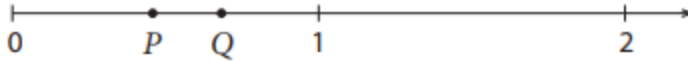
D R280

7. The fractions $\frac{4}{14}$ and $\frac{[\]}{21}$ are equivalent.

What is the value of []?

- A 6
- B 7
- C 11
- D 14
8. A workman cut off $\frac{1}{5}$ of a pipe. The piece he cut off was 3 metres long.
How many metres long was the original pipe?
- A 8 m
- B 12 m
- C 15 m
- D 18 m
9. Which shows a correct method for finding $\frac{1}{3} - \frac{1}{4}$?
- A $\frac{1 - 1}{4 - 3}$
- B $\frac{1}{4 - 3}$
- C $\frac{3 - 4}{3 \times 4}$
- D $\frac{4 - 3}{3 \times 4}$

10.

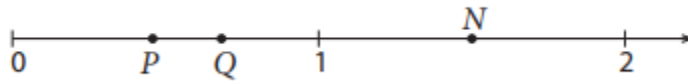


P and Q represent two fractions on the number line above.

$$P \times Q = N$$

Which of these shows the location of N on the number line?

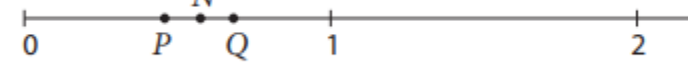
A



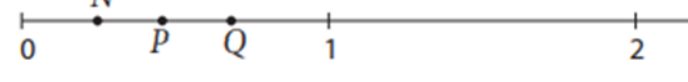
B



C



D



11. There were m boys and n girls in a parade. Each person carried 2 balloons. Which of these expressions represents the total number of balloons that were carried in the parade?

A $2(m + n)$

B $2 + (m + n)$

C $2m + n$

D $m + 2n$

12. If t is a number between 6 and 9, then $t + 5$ is between which two numbers?

- A 1 and 4
- B 10 and 13
- C 11 and 14
- D 30 and 45

13. What is the value of $\frac{1}{8} + \frac{1}{3}$?

- A $\frac{2}{11}$
- B $\frac{1}{24}$
- C $\frac{1}{11}$
- D $\frac{11}{24}$

14. What does $xy + 1$ mean?

- A Add 1 to y , then multiply by x
- B Multiply x and y by 1
- C Add x to y , then add 1
- D Multiply x by y , then add 1

15. Which expression is equivalent to $4(3 + x)$?

A $12 + x$

B $7 + x$

C $12 + 4x$

D $12x$

16. Which of these is equal to $3p^2 + 2p + 2p^2 + p$?

A $8p$

B $8p^2$

C $5p^2 + 3p$

D $7p^2 + p$

17. A piece of wood was 40cm long.

It was cut into 3 pieces.

The lengths in cm are:

$2x - 5$

$x + 7$

$x + 6$

The length of the longest piece is:

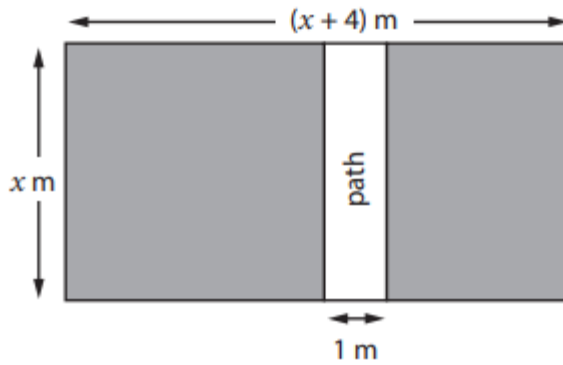
A 8 cm

B 15 cm

C 14 cm

D 11 cm

18.



This is a diagram of a rectangular garden.

The white area is a rectangular path that is 1 metre wide.

Which expression shows the area of the shaded portion of the garden in m^2 ?

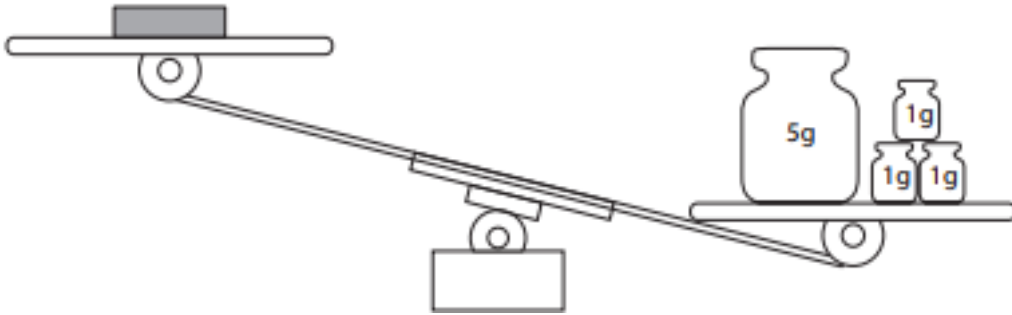
- A $x^2 + 3x$
- B $x^2 + 4x$
- C $x^2 + 4x - 1$
- D $x^2 + 3x - 1$

19. What is the sum of three consecutive whole numbers with $2n$ as the middle number?

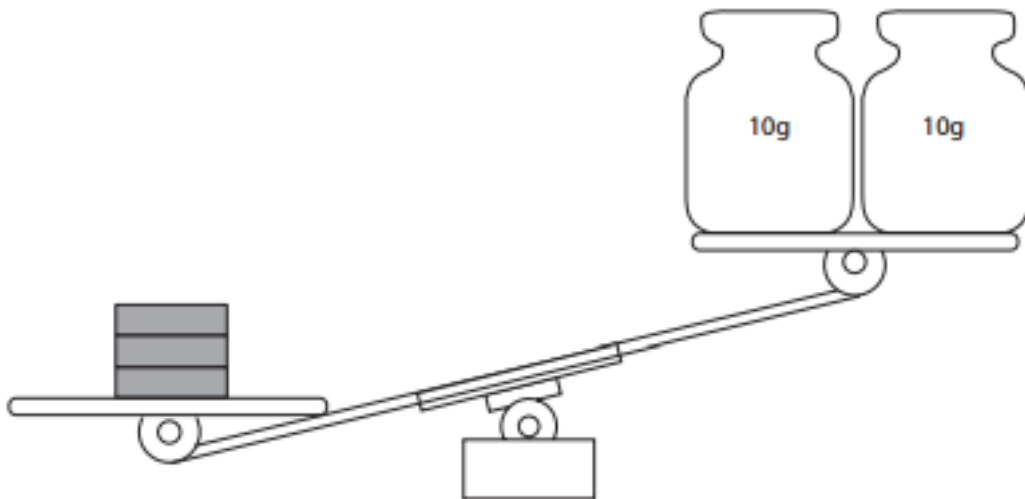
- A $6n + 3$
- B $6n$
- C $6n - 1$
- D $6n - 3$

20. Jo has three metal blocks. The weight of each block is the same.

When she weighed one block against 8 grams, this is what happened.



When she weighed all three blocks against 20 grams, this is what happened.



Which of the following could be the weight of one metal block?

- A 5 g
- B 6 g
- C 7 g
- D 8 g

Name

Class

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- 1 ☐ A ☐ B ☐ C ☐ D 11 ☐ A ☐ B ☐ C ☐ D
- 2 ☐ A ☐ B ☐ C ☐ D 12 ☐ A ☐ B ☐ C ☐ D
- 3 ☐ A ☐ B ☐ C ☐ D 13 ☐ A ☐ B ☐ C ☐ D
- 4 ☐ A ☐ B ☐ C ☐ D 14 ☐ A ☐ B ☐ C ☐ D
- 5 ☐ A ☐ B ☐ C ☐ D 15 ☐ A ☐ B ☐ C ☐ D
- 6 ☐ A ☐ B ☐ C ☐ D 16 ☐ A ☐ B ☐ C ☐ D
- 7 ☐ A ☐ B ☐ C ☐ D 17 ☐ A ☐ B ☐ C ☐ D
- 8 ☐ A ☐ B ☐ C ☐ D 18 ☐ A ☐ B ☐ C ☐ D
- 9 ☐ A ☐ B ☐ C ☐ D 19 ☐ A ☐ B ☐ C ☐ D
- 10 ☐ A ☐ B ☐ C ☐ D 20 ☐ A ☐ B ☐ C ☐ D

Stage 1 - Answer Grid (4300)

Name

Class

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- 1 ☐ A ☐ B ☐ C ☐ D 11 ☐ A ☐ B ☐ C ☐ D
- 2 ☐ A ☐ B ☐ C ☐ D 12 ☐ A ☐ B ☐ C ☐ D
- 3 ☐ A ☐ B ☐ C ☐ D 13 ☐ A ☐ B ☐ C ☐ D
- 4 ☐ A ☐ B ☐ C ☐ D 14 ☐ A ☐ B ☐ C ☐ D
- 5 ☐ A ☐ B ☐ C ☐ D 15 ☐ A ☐ B ☐ C ☐ D
- 6 ☐ A ☐ B ☐ C ☐ D 16 ☐ A ☐ B ☐ C ☐ D
- 7 ☐ A ☐ B ☐ C ☐ D 17 ☐ A ☐ B ☐ C ☐ D
- 8 ☐ A ☐ B ☐ C ☐ D 18 ☐ A ☐ B ☐ C ☐ D
- 9 ☐ A ☐ B ☐ C ☐ D 19 ☐ A ☐ B ☐ C ☐ D
- 10 ☐ A ☐ B ☐ C ☐ D 20 ☐ A ☐ B ☐ C ☐ D

Stage 1 - Answer Grid (4300)

Name: _____

Stage 2: Pre-Intervention Learner Survey [10 minutes]

*Thank you for taking the time to fill this out!
Do not leave any questions out.*

1. Are you male or female?

Male	
Female	

2. Which language do you speak at home? (Tick the columns that apply)

	Mostly	Sometimes	Never
English			
Afrikaans			
Xhosa			
Other			

3. About how many books are there in your home? (Do not count magazines, newspapers or your school books?)

None or very few (0-10 books)	
Enough to fill one shelf (11-25 books)	
Enough to fill one bookcase (26-100 books)	
Enough to fill two bookcases (101-200 books)	
Enough to fill three or more bookcases (more than 200 books)	

4. Do you have any of these in your home?

	YES	NO
A computer or tablet of your own		
A computer or tablet that is shared with other people		
Study/desk/table for your use		
Your own room		
Internet connection		
Your own mobile phone		

5. Do your mother and father work? Tick the appropriate box. If you come from a single parent household select n/a.

	Employed	Unemployed	n/a
Mother			
Father			

6. What is the highest level of education completed by your mother?

Did not go to school	
Some primary education	
Some secondary education	
Went to a college/technikon	
Undergraduate degree from a university	
Postgraduate degree (Masters or a PhD)	
I don't know	

7. What is the highest level of education completed by your father?

Did not go to school	
Some primary education	
Some secondary education	
Went to a college/technikon	
Undergraduate degree from a university	
Postgraduate degree (Masters or a PhD)	
I don't know	

8. Which method do you think will help you learn mathematics the best? Select only one

Trying to understand worked-examples	
Learning the formulas my teacher gives me	
Practicing with questions over and over again	

9. How much do you agree with these statements?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
I enjoy reading about mathematics				
I look forward to my mathematics				
I do mathematics because I enjoy it				
I am interested in the things I learn in mathematics				

10. How much do you agree with these statements about studying mathematics?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
I often worry that it will be difficult for me in the mathematics classes				
I get very tense when I have to do mathematics homework				
I get very nervous doing mathematics problems				
I feel helpless when doing a mathematics problem				
I worry that I will get poor grades in mathematics				
I am confident to do maths on my own at home or in class.				

11. Please select only one statement that best describes your approach to mathematics:

When I study for a mathematics test, I try to figure out what are the most important parts to learn	
When I study for a mathematics test, I try to understand new concepts by relating them to things I already know	
When I study for a mathematics test, I learn as much as I can by heart	

12. Please select only one statement that best describes your approach to learning mathematics in class:

I learn mathematics by making notes on the rules and reading over them again and again until I know them all by heart	
I learn mathematics by going over problems again and again until I can solve them in my sleep	
I learn mathematics by looking at many different worked-examples and try to find out the best way to solve the problem	

13. Rate what you think your Mathematical ability is.

I am very weak	
I am weak	
I am average	
I am strong	
I am very strong	

14. How strongly do you agree or disagree with this statement:

I have different strategies which I use to learn Mathematics.

Strongly Agree	
Agree	
Disagree	
Strongly Disagree	

15. Please select one option for each question:

	Yes, I am very good	I can do it most of the time	I can do it sometimes but I am a bit unsure	I don't know how to do that
I can add and subtract any fraction				
I know how to multiply fractions				
I know how to divide fractions				
I know how to simplify algebraic expressions				
I know how to solve algebraic equations				

16. Please select one option for each question:

	All the time	Most of the time	Sometimes	Never or hardly ever
How often do you need your teacher to explain something to you?				
How often do you ask your friends or family for help with mathematical problems?				

17. I would love to hear your views about the new teaching method that will be used this week. Would you be willing to be interviewed about the process after it has taken place?

Yes	
No	

18. Please indicate your interview preference:

Group interview	
Individual interview	
Don't mind	

Page left intentionally blank.

Name: _____

[\[Click here to go back to text\]](#)

STAGE 3: Group Work [20 minutes]



Instructions:

Work as a pair to revise how to simplify fractions and algebraic expressions!

At the end of each example are some practice questions. Do all of these and then check your answers on the last page.

NO CALCULATORS ALLOWED

RULES FOR GROUP WORK:

1. Listen to everyone's idea
2. Discuss positive and negative aspects of each person's idea
3. Determine, as a group, which ideas you feel are most valid
4. Allow everyone a turn to put forward their opinions on the group-chosen idea
5. Decide together what conclusions you will make.

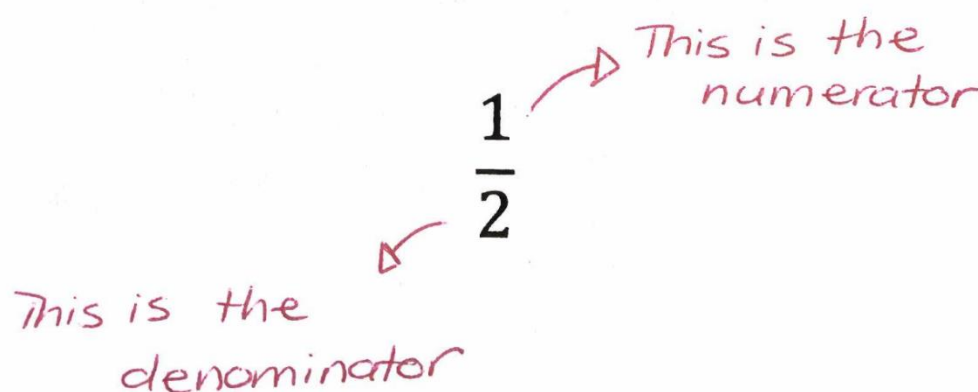


Diagram illustrating the components of a fraction:

$$\frac{1}{2}$$

The top number (1) is labeled "This is the numerator".

The bottom number (2) is labeled "This is the denominator".

Example 1: Adding and Subtracting Fractions

$$\frac{1}{2} + \frac{3}{5}$$

We need to make the bottom numbers the same.
i.e. we need to find the lowest common denominator (LCD)

$$= \frac{1 \times 5}{2 \times 5} + \frac{3 \times 2}{5 \times 2}$$

The LCD is 10 so we need to x the first fraction by 5 and the second one by 2

$$= \frac{5}{10} + \frac{6}{10}$$

Once the denominators (the bottom numbers) are the same, we can add the top numbers.

$$= \frac{11}{10}$$

* Don't add the bottom numbers *

Practice: (Leave your answers as improper fractions)

1. $\frac{3}{4} + \frac{5}{6}$

2. $\frac{6}{7} - \frac{13}{49}$

Example 2: Multiplying Fractions

$$1\frac{3}{7} \times \frac{21}{10}$$

Convert all mixed numbers to improper fractions

$$= \frac{10}{7} \times \frac{21}{10}$$

$$= \frac{10^1}{7_1} \times \frac{21^3}{10^1}$$

Cross-cancel!
You can only cancel top numbers with bottom numbers

$$= \frac{3}{1}$$

$$= 3$$

any whole number can be written over 1
i.e. $5 = \frac{5}{1}$

Practice: (Leave your answers as improper fractions)

3. $\frac{3}{4} \times \frac{16}{9}$

4. $1\frac{2}{3} \times 2\frac{7}{10}$

Example 3: Dividing Fractions

$$1\frac{3}{5} \div \frac{15}{16}$$

change to an improper fraction

$$= \frac{8}{5} \div \frac{15}{16}$$

$$= \frac{8}{5} \times \frac{16}{15}$$

only the second fraction
Tip and Times

$$= \frac{\cancel{8}^1}{\cancel{5}_2} \times \frac{15^3}{16^2}$$

$$= \frac{3}{2}$$

Practice:

5. $\frac{5}{9} \div \frac{20}{27}$

6. $1\frac{2}{3} \div \frac{20}{27}$

Example 4: Algebraic simplification

1. Simplify: $2 \times x = 2x$

2. Simplify: $x \times x = x^2$

3. Simplify: $10x - 7x = 3x$

4. Simplify: $2(x + 1)$
 $= 2x + 2$

multiply every number in the bracket by the number outside the bracket.

5. Simplify: $2x + 4 - x + 6$

Group like terms together : x 's with x 's and numbers with numbers.

$$= 2x - x + 4 + 6$$

Simplify

$$= x + 10$$

Simplify

Practice:

7. $3 \times x =$

8. $15x - 10x =$

9. $3(2x + 1) =$

10. $3 \times a + 4 \times b =$

11. $8x - 2 - 5x + 5$

Check your answers:

1. $\frac{19}{12}$

2. $\frac{29}{49}$

3. $\frac{4}{3}$

4. $\frac{9}{2}$

5. $\frac{3}{4}$

6. $\frac{9}{4}$

7. $3x$

8. $5x$

9. $6x + 3$

10. $3a + 4b$

11. $3x + 3$

Name: _____

[\[Click here to go back to text\]](#)

STAGE 4: Individual Work

[30 minutes]

Instructions:

1. There are 8 different worked-examples given in this sheet.
2. They are all incomplete in a different way.
3. Follow the instructions to complete each example AND the rating scale at the end of each question.
4. Calculators are allowed!

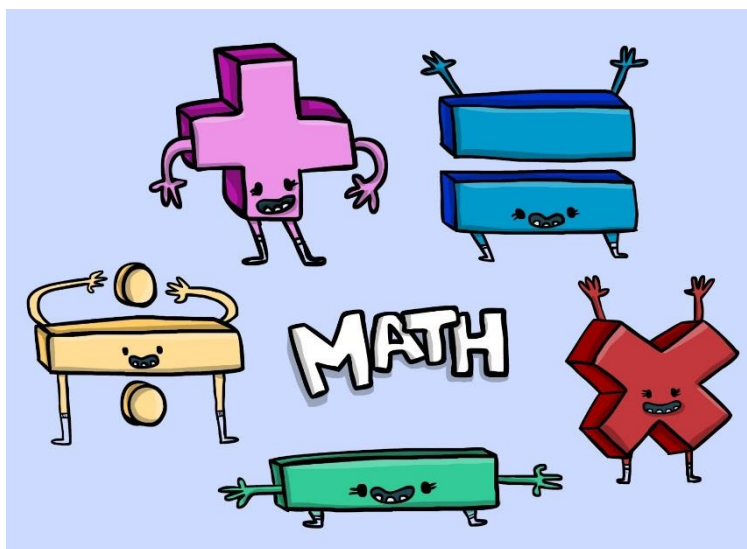
pure
MATHEMATICS
is, in its own
Way, the
POETRY
of logical ideas



ALBERT EINSTEIN

The only way
to learn
mathematics
is to do
mathematics.

PAUL HALMOS



Worked-example 1

Terms have been omitted from the worked-example below. Omitted terms are indicated by []. Fill in the missing terms.

Simplify the following algebraic fraction:

$$\frac{7}{5} - \frac{2}{3}$$

$$= \frac{7 \times 3}{5 \times 3} - \frac{2 \times 5}{3 \times 5}$$

Our lowest common denominator is 15!

$$= \frac{21 - 10}{15}$$

$$= \frac{[\quad]}{15} \rightarrow \text{Fill in this block.}$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 2[\[Click here to go back to text\]](#)

Terms have been omitted from the worked-example below. Omitted terms are indicated by []. Fill in the missing terms.

Simplify the following algebraic fraction:

$$\frac{3x}{2} + \frac{4x}{3}$$

$$= \frac{3x \times [\quad]}{2 \times 3} + \frac{[\quad]}{3 \times [\quad]}$$

What is the lowest number that 2 and 3 can divide into?
i.e. What is the lowest common denominator?

$$= \frac{[\quad] + [\quad]}{6}$$

$$= \frac{[\quad]}{6}$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 3

Terms AND WORDS FROM THE EXPLANATIONS have been omitted from the worked-example below. Omitted terms and words are indicated by []. Fill in the missing terms and words.

Simplify the following algebraic fraction:

$$\frac{2x}{3} - \frac{x}{4}$$

$$= \frac{2x \times []}{3 \times []} - \frac{x \times []}{4 \times []}$$

In order to add/subtract fractions the [] need to be the same. So we [] the denominator by a certain number, but we also have to [] the numerator by the same number to keep the value of the fraction the same.

$$= \frac{[] - []}{[]}$$

$$= \frac{[]}{[]}$$

When the denominators are all the same, we can put all the individual fractions over one denominator.

Once we have one fraction we need to [] the numerators.

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 4

In this worked-example there is a mistake.

Circle the mistake and correctly complete the example using the lines provided on the right of the page.

Simplify the following fraction:

$$\frac{3a}{5} + \frac{a}{2}$$

$$= \frac{3a+a}{5+2}$$

$$= \frac{4a}{7}$$

[illegible]

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 5

This worked-example has been started for you.

Your task is to complete the calculations to get to the final answer that is given.

Use the spaces provided to complete the example.

Simplify the following fraction:

$$\frac{5a}{14} \div \frac{15}{7} + \frac{a}{6}$$

BODMAS $\rightarrow$ we $\div$ before $+$

$$= \left(\frac{5a}{14} \div \frac{15}{7} \right) + \frac{a}{6}$$

$$= \left(\frac{5a}{14} \times \frac{[\quad]}{[\quad]} \right) + \frac{a}{6}$$

Complete the example here



$$= \frac{a}{3}$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 6

Simplify the fraction given below so that it gives the answer at the end of the page. Use the space in the middle of the page for your calculations.

$$\frac{x}{2} \div \frac{5x}{6} + \frac{2}{5}$$

$$= 1$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 7

Terms have been omitted from the worked-example below. Omitted terms and words are indicated by []. Fill in the missing terms to get the answer at the end.

Simplify the following algebraic fraction:

$$\frac{x}{2} - \frac{2x}{5} + \frac{x+1}{10}$$

$$= \frac{x \times []}{2 \times []} - \frac{2x \times []}{5 \times []} + \frac{(x+1)}{10}$$

$$= \frac{[] - [] + x + 1}{[]}$$

$$= \frac{2x + 1}{10}$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Worked-example 8

Simplify the fraction given below so that it gives the answer at the end of the page. Use the space in the middle of the page for your calculations.

$$\frac{x^2}{2} \div \frac{5x}{6} + \frac{x+2}{10}$$

$$= \frac{7x+2}{10}$$

Please indicate how difficult you found this question:

1	2	3	4	5	6	7	8	9
Very, very easy	Very easy	Easy	Rather easy	Neither easy nor hard	Rather hard	Hard	Very hard	Very, very hard

If you found it hard, please indicate why:

	The instructions were confusing
	I couldn't work out the numbers
	I don't know how to do fractions
	I don't know how to do algebra
	There were too many bits of information and I got confused
	I use a different method so I had to think hard about how this method was working
	The examples were too long and I couldn't focus till the end

Which example helped you learn best? Select all that apply.

	Worked-example 1
	Worked-example 2
	Worked-example 3
	Worked-example 4
	Worked-example 5
	Worked-example 6
	Worked-example 7
	Worked-example 8
	None of the examples

Please provide a brief reason for your choice:

Name: _____

[\[Click here to go back to text\]](#)

STAGE 5 [20 minutes]

Instruction: Attempt all 6 questions. Show all working. Try the Bonus question if you have time!

Leave your answers as IMPROPER fractions.

NO CALCULATORS

1. Simplify:

$$\frac{1}{2} + \frac{3}{5}$$

2. Simplify:

$$\frac{x}{4} + \frac{5}{3}$$

3. *Simplify:*

$$\frac{2x}{5} - \frac{3x}{4}$$

4. *Simplify:*

$$\frac{7x}{5} - \frac{x}{2} + \frac{x}{10}$$

5. Simplify:

$$\frac{2}{x} + \frac{3}{y}$$

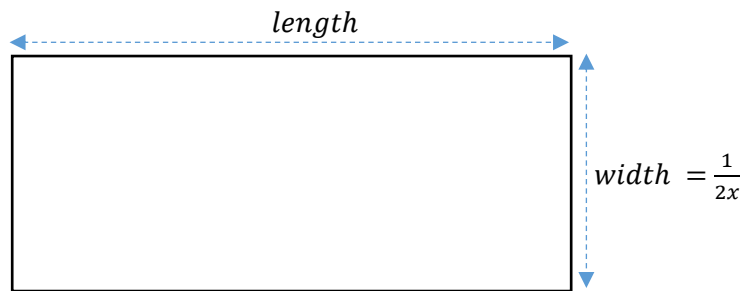
6. Simplify:

$$\frac{3x^2}{5} \div \frac{2x}{15} \times \frac{2x}{3}$$

Bonus Question

In the rectangle shown below, the length is double the width.

If the width is $\frac{1}{2x}$ units long, determine the perimeter of the rectangle in terms of x .



Name: _____

Stage 6 - Post-Intervention Learner Survey [10-15 minutes]

Thank you for taking the time to fill this out!

*Only tick **ONE** box that applies to you. Do not leave any questions out.*

1. Which method do you think will help you learn mathematics the best? Select only one

Trying to understand worked-examples	
Learning the formulas my teacher gives me	
Practicing with questions over and over again	

2. How much do you agree with these statements?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
I enjoy reading about mathematics				
I look forward to my mathematics				
I do mathematics because I enjoy it				
I am interested in the things I learn in mathematics				

3. How much do you agree with these statements about studying mathematics?

	Agree a lot	Agree a little	Disagree a little	Disagree a lot
I often worry that it will be difficult for me in the mathematics classes				
I get very tense when I have to do mathematics homework				
I get very nervous doing mathematics problems				
I feel helpless when doing a mathematics problem				
I worry that I will get poor grades in mathematics				
I am confident to do maths on my own at home or in class.				

4. Please select only **ONE** statement that **BEST** describes your approach to mathematics:

When I study for a mathematics test, I try to figure out what are the most important parts to learn	
When I study for a mathematics test, I try to understand new concepts by relating them to things I already know	
When I study for a mathematics test, I learn as much as I can by heart	

5. Please select only **ONE** statement that **BEST** describes your approach to learning mathematics in class:

I learn mathematics by making notes on the rules and reading over them again and again until I know them all by heart	
I learn mathematics by going over problems again and again until I can solve them in my sleep	
I learn mathematics by looking at many different worked-examples and try to find out the best way to solve the problem	

6. Rate what you think your Mathematical ability is.

I am very weak	
I am weak	
I am average	
I am strong	
I am very strong	

7. How strongly do you agree or disagree with this statement:

I have different strategies which I use to learn Mathematics.

Strongly Agree	
Agree	
Disagree	
Strongly Disagree	

8. Please select **ONE** option for each question:

	Yes, I am very good	I can do it most of the time	I can do it sometimes but I am a bit unsure	I don't know how to do that
I can add and subtract any fraction				
I know how to multiply fractions				
I know how to divide fractions				
I know how to simplify algebraic expressions				
I know how to solve algebraic equations				
I know how to simplify algebraic equation like the ones I was doing this week				

9. Please select **one** option for each question:

	All the time	Most of the time	Sometimes	Never or hardly ever
During the worked-example activity, how often did you feel that you needed your teacher to explain the maths to you?				
How often did you ask your friends for help with mathematical problems?				

10. How well do you think you were able to complete the worked-examples given in class?

I think I did well and got most of the answers correct	
I think I did ok and got some of the answers correct	
I don't think I did too well and I got a few answers wrong	
I don't think I did too well and got many answers wrong	

11. During this week, did you at any point realise that your prior understandings of fractions or algebra were incorrect?

No, all my prior understandings were correct	
Yes, but only a few times	
Yes, there were many times	
I am not sure	

12. Did you find that completing the worked-examples helped you understand how to do algebraic fractions?

Definitely NO	Not really	Kind of	Definitely YES
---------------	------------	---------	----------------

Please briefly explain your selection above.

13. After this week, would you like your teacher to use worked-examples like this more in class?

No	I am not sure	Yes
----	---------------	-----

14. I would love to hear your views about the new teaching method that will be used this week. Would you be willing to be interviewed about the process after it has taken place?

Yes	
No	

15. Please indicate your interview preference:

Group interview	
Individual interview	
Don't mind	

STAGE 6: Post-intervention Teacher Survey

Thank you for taking the time to complete this survey. You will have an opportunity to discuss anything with me during the interview.

1. Do you think the students were engaged in the lessons? What makes you think this?

2. Do you think the students learned effectively during the two lessons that you observed? What makes you think this?

3. Did anything happen in the lessons that struck a chord with you? If yes, please explain what these were.

4. Do you think that students can learn more effectively by completing worked-examples? Please provide a brief explanation of your thoughts.

5. Do you think there are any potential negative consequences of this approach? Please provide a brief explanation of your thoughts.

6. Was there an aspect of the lessons that you feel could be improved upon? If yes, please elaborate on your thoughts.

7. Do you have any questions that you would like to ask me, or any queries about the lessons you observed?

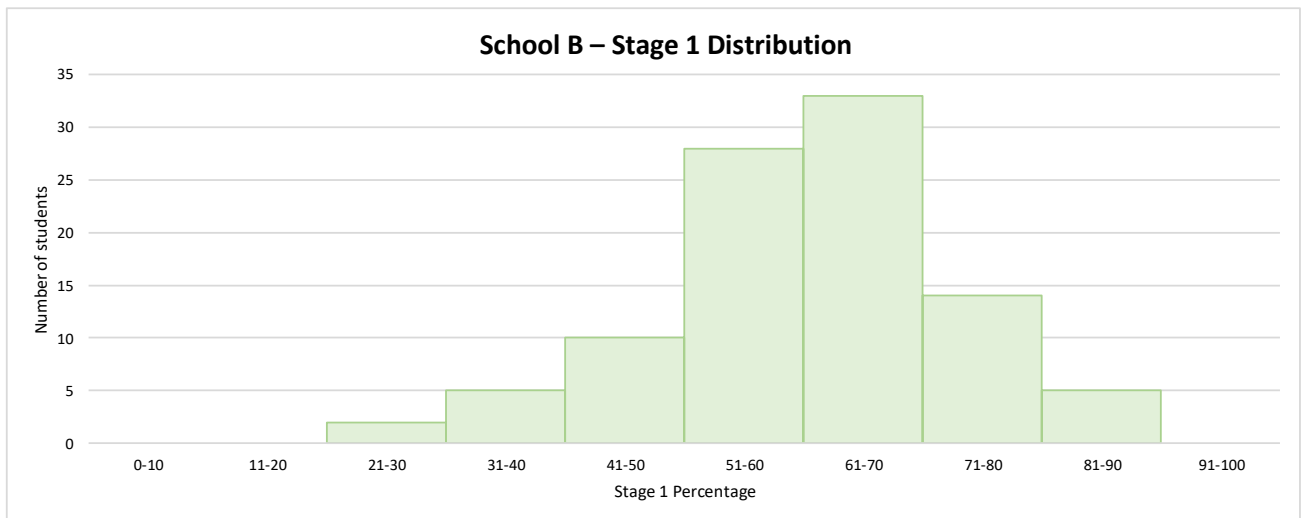
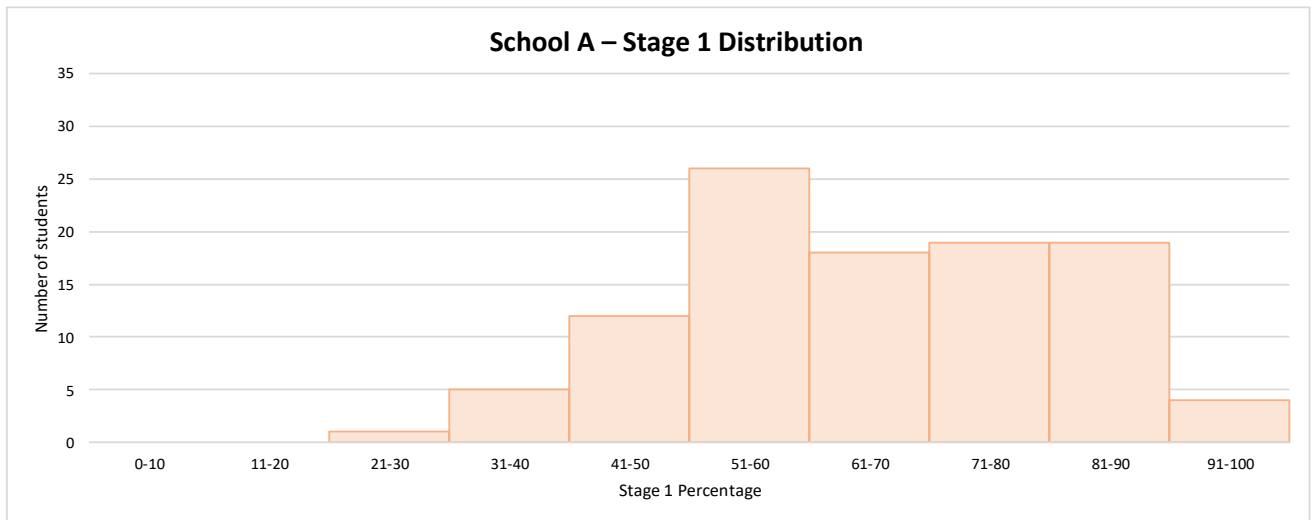
Stage 7

Student Interview Questions

1. How does your teacher normally teach you in class?
2. Compared to how your teacher normally teaches you, how did you find working with the worked-examples in class?
3. Do you think you learned how to do algebraic fractions by completing the worked-examples? Why do you think so or not?
4. What did you like about the worked examples?
5. What did you not like about the worked examples?
6. Do you think that you can learn more in Mathematics by analysing worked-examples in any topic? Why do you think so or not?
7. While you were studying the worked-examples did you notice that there were some areas that you didn't quite understand? What were these?
8. Do you think that analysing worked-examples can help you learn Mathematics on your own? Why do you think so or not?

Appendix 2: Stage 1 Performance Distribution

[\[Click here to go back to text\]](#)



COLLEGE NEWS

MATHEMATICS

TERM 2 | 2018

Cognitive processing and Mathematics

AS RESEARCH SHEDS NEW LIGHT ON COGNITIVE FUNCTIONS, CLASSROOM PRACTICES NEED TO BE UPDATED TO ACCOMMODATE THESE NEW FINDINGS.

Cognitive Load Theory

Developed by John Sweller in the 1980's, Cognitive Load Theory details how long and short-term memory work together in order for learning to occur. Sweller, (1985) suggests that humans have an unlimited long-term memory store, but a very limited working-memory capacity - and it is our working-memory that is seen to limit the rate at which knowledge is acquired. Humans are said to be able to process only 4-7 chunks of information at a time in working-memory. As a result, learning materials need to take this into account and reduce the presence of objects that would require mental processing and cause unnecessary mental load.

Explorations with the Grade 9's

During my tenure at [REDACTED] I have been in the process of completing my Master's degree. During this time I have delved into the depths of Cognitive Load Theory and it's associated instructional suggestions. One of these being the use of worked-examples in Mathematics, which has been shown to improve learning and also reduce the amount of time it takes to understand new work.

The Grade 9's took part in this research in 2017, and results showed that they were able to analyse worked-examples to help them learn new content on algebraic fractions. The Grade 9's did this without my assistance and it really highlighted that, with a little bit of concentration and analysis, they are definitely able to self-regulate their own learning. They also realized this, and some even said that it taught them how to use their textbooks when they were stuck.

Additionally, girls also showed a much higher preference for the use of worked-examples than the boys did, eluding to the possibility that boys and girls may actually learn in different ways! However, this is not new knowledge and, indeed, boys and girls have not only shown differential preferences when it comes to learning (Andreano & Cahill, 2009), but research has also highlighted that their brains are also structurally different (Zaidi, 2010).

This highlights that education cannot adopt a "one size fits all" approach.

[REDACTED]

References:

Sweller, J., & Cooper, G. (1985). The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra. *Cognition and Instruction*, 2(1), 59-89.

Andreano, J. M., & Cahill, L. (2009). Sex influences on the neurobiology of learning and memory. *Learning & Memory*.

Zaidi, Z. F. (2010). Gender differences in human brain: a review. *The Open Anatomy Journal*, 2, 37-55.

Appendix 4: Letter to Headteacher

[\[Click here to go back to text\]](#)

UNIVERSITY OF OXFORD DEPARTMENT OF EDUCATION

15 Norham Gardens, Oxford OX2 6PY
Tel: +44(0)1865 274024 Fax: +44(0)1865 274027
general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

Director Professor Jo-Anne Baird



I am writing to enquire about conducting research in school this academic year. As you know, I am studying for the Master's in Learning and Teaching at Oxford University, supervised by Jenni Ingram. In my final research project "An Exploration into Gender and Sociocultural Differences within the Worked-Example Effect in Secondary School Mathematics Classrooms". In my final research project, I will be investigating three main areas, i) student and teacher perceptions surrounding the use of worked-examples in the mathematics classroom, ii) student performance during and after the use of worked-examples and, iii) changes in perception towards learning and teaching due to the use of worked-examples as an exercise in the classroom.

The research will take place with all the Grade 9 students and teachers. The teachers will be implementing an intervention that is an exercise on algebraic fractions - presented only through the use of worked-examples. Students and teachers will also complete pre- and post-intervention surveys to allow for an exploration into possible changes in their approach towards learning and teaching. In doing this research, I hope to enhance student learning by decreasing negative working memory load and explore possible differences between students of different gender and socioeconomic status. [REDACTED] has also agreed to take part in this research and I am hoping you will do so to.

By participating in the research, the school would be contributing to a project that will deepen our understanding of mathematics learning for students of both low and high prior attainment, and so contribute towards developing ways of improving attainment for these students in the school in the future. It will also contribute to Mathematics education more widely.

I hope to conduct this research between January and May 2018. Within this time frame, I will spend one-hour explaining my research to the teachers and how the intervention will take place. After this, the students and teachers will complete pre- and post-intervention surveys and take part in the intervention as stated in paragraph 2. For this intervention, approximately 2-4 lessons will be needed. However, the students will still be learning material that is stipulated within the curriculum, thus no teaching time will be unnecessarily lost. I will also conduct an audio-recorded

interview with the students and teachers who have given me consent to do so at the end of the intervention and at a convenient time for all parties involved.

Oxford University has strict ethical procedures on conducting ethical research, consistent with current British Educational Research Association guidelines. The University also recognises, however, that my study is a piece of practitioner research, and that schools already operate with the highest ethical standards. Therefore only your formal consent as headteacher is necessary, and not that of individual parents or staff. However, throughout the research, students and other teachers will be able to refuse to participate in any research activities at any time.

All participants, including students, teacher and the school, would be made anonymous in all research reports. The data collected would be kept strictly confidential, available only to my supervisor Jenni Ingram () and me, and only used for academic purposes. It will be kept for as long as it has academic value.

If you are happy for me to proceed with this study, please confirm that using the attached reply form. If you have any concerns or need more information about what is involved, please contact me or my supervisor. Further, if you have any questions about this ethics process at any time, please contact the chair of the department's research ethics committee, though: research.office@education.ox.ac.uk

I look forward to hearing from you.

Yours sincerely,



CONSENT FORM FOR HEAD TEACHER

An Exploration into Gender and Sociocultural Differences within the Worked-Example Effect in Secondary School Mathematics Classrooms

Declaration of Consent

I have been informed about the aims and procedures involved in the research project described above.

I reserve the right to withdraw any child at any stage in the proceedings and also to terminate the project altogether if I think it necessary.

I understand that the information gained will be anonymous and that children's names and the school's name will be removed from any materials used in the research.

- ☐ We do not wish to participate in this project.
- ☐ We would like to find out more about this project.
- ☐ We would like to take part in this project.

Name: _____

Signed: _____

School: _____

Date: _____

Thank you for your help.

School A consent:

University of Oxford	Department of Education
CONSENT FORM FOR HEAD TEACHER	
<i>An Exploration into Gender and Sociocultural Differences within the Worked-Example Effect in Secondary School Mathematics Classrooms</i>	
Declaration of Consent	
I have been informed about the aims and procedures involved in the research project described above.	
I reserve the right to withdraw any child at any stage in the proceedings and also to terminate the project altogether if I think it necessary.	
I understand that the information gained will be anonymous and that children's names and the school's name will be removed from any materials used in the research.	
☐ We do not wish to participate in this project.	
☐ We would like to find out more about this project.	
☒ We would like to take part in this project.	
Name: _____	
Signed: _____	
School: _____	
Date: _____	
<i>Thank you for your help.</i>	

School B consent:

CONSENT FORM FOR HEAD TEACHER	
<i>The Worked-Example Effect: An Exploration into Gender and Socioeconomic Differences of Grade 9 Mathematics Students in Two South African Schools.</i>	
Declaration of Consent	
I have been informed about the aims and procedures involved in the research project described above.	
I reserve the right to withdraw any child at any stage in the proceedings and also to terminate the project altogether if I think it necessary.	
I understand that the information gained will be anonymous and that children's names and the school's name will be removed from any materials used in the research.	
☐ We do not wish to participate in this project.	
☐ We would like to find out more about this project.	
☒ We would like to take part in this project.	
Name: _____	
Signed: _____	
School: _____	
Date: _____	

Appendix 5: Letter to parents and parent consent for interview

[Click here to go back to text]



9A

Dear Parents

RE: REQUEST FOR PERMISSION TO DO RESEARCH WITH [REDACTED]

I would like to ask your permission to conduct research with your child at Nomzamo High School on one day during May 2018. Part of my research project involves interviewing some of the Grade 9 students on the new approach their teacher used to teach them algebraic fractions in mathematics. It will involve a short interview with the students in a group. This interview will be recorded so that I can analyse their answers after the interview has been completed.

It is my presumption that the research findings will help teachers find more productive ways to teach the students in their class and also to show students how they can use worked-examples in mathematics to aid their own learning. Ultimately, I hope to find new teaching methods that will allow for improved learning and results in mathematics.

In order to conduct this research and record the interviews, I need your permission to do so. The recorded material can also be made available to you should you wish to listen to it. The information obtained will be treated with the strictest confidentiality and will be used solely for this research purposes only.

If you are willing to let your child participate in this study, please sign this letter as a declaration of your consent, i.e. that you allow for them to participate in this project willingly and that you understand that you/they may withdraw from the research project at any time. Under no circumstances will the identity of interview participants be made known to any parties/organizations that may be involved in the research process.

Mr Mgubantu, the Principal, is aware of the study and has granted his consent.

If you have any queries, please contact me on [REDACTED]

Yours sincerely

PLEASE COMPLETE THE SECTION BELOW AND ASK YOUR CHILD TO BRING THIS LETTER BACK TO SCHOOL

I ALLOW my child in Grade 9 at [REDACTED]

day in May of 2018. I also grant her permission to record the interview.

Name: [REDACTED]

Signed [REDACTED]

Date: [REDACTED]

Exploring Gender and Sociocultural
Differences within the Worked-
Example Effect in Secondary School
Mathematics Classrooms

Oxford University



Department of Education

Dear Parent or Guardian,

I am writing to invite your child to take part in my research study, with the rest of his or her Grade 9 maths class. You may be aware that your child's school has agreed to take part in a research study.

Understanding and learning are crucial aspects for student performance in mathematics. There is research evidence that tells us how to enhance both understanding and learning in our mathematics classrooms. I am investigating how different students benefit from using worked-examples in their mathematics class, with particular interest in raising the attainment of students who have repeatedly shown to underperform when compared to others. In particular, I will be assessing how students from different genders and socioeconomic backgrounds learn with the use of worked-examples. I have chosen to work with your child's maths group because this group is starting to learn how to simplify algebraic fractions – a topic that is often quite difficult for the students to grasp. The research aims to help improve student understanding of how to simplify algebraic fractions with the ultimate goal of discovering ways of improving learning in the mathematics classroom on the whole.

I hope that your child will want to take part in the research, but before you decide, it is important that you understand what it will involve. Please take some time to read through the information on this pamphlet.


Oxford University Department of Education



Who is running the research?

I am a part-time student at the Department of Education at the University of Oxford, completing a Master's of Science in Learning and Teaching. I am also a fully qualified and experienced secondary mathematics teacher, and live and work in Cape Town. A more experienced researcher, Dr Jenni Ingram, supervises my research.



What will your child be asked to do?

Your child's teacher will plan and run normal maths lessons. Students will be following their usual curriculum. Between February and April 2018 the student will take part in the research outlined below.

Everyone will complete a fractions and algebra assessment to see if they have any gaps in their knowledge. They will then answer some questions about how they feel towards mathematics in a questionnaire. Everyone will then complete six worked-examples, given to them by their teacher. Their teacher will be there to answer any of their questions the whole time! After this, they will do a short 6 question assessment to see if they can apply what they have learned, followed by another questionnaire to determine how they felt about the whole process. In this questionnaire students will be invited to an interview (individual or group depending on their preference). The students who would like to be interviewed will then be invited to talk about the process and how they felt about it – this will be audio taped so that I do not have to try and remember everything they say! The students will not have to do anything that they do not want to do and can opt-out of the research at any time.

In order to compensate students for their help with the study, I will sometimes work with your child's maths teacher as a classroom assistant in lessons. This will help the teacher in supporting students' learning.

Ethics

Any research with young people needs to be conducted with care and sensitivity. Some students might feel shy about having a researcher in the classroom, and they might feel concerned about being audio recorded in the interview.

My research will be consistent with the strict guidelines required by Oxford University and the Western Cape Education Department. Your child's school has agreed to participate in the research. Taking part in this research is completely voluntary. You and your child are free to say you do not want to participate.

Your child will be free to withdraw from the research at any point, without giving any reason. This would not affect your child's education in any way.

I will make the data I collect in the study anonymous. Audiotapes, my notes, and all other data will be stored in a locked office in my own home in Cape Town. I will also maintain confidentiality consistent with current UK and SA law. Your child's school will not have access to the data, and no one other than me, and my supervisor, will see the data. If I wanted to use the data for any other purpose, I would have to contact you and obtain your permission. At the end of the study, the audio recordings will be erased and personal data destroyed.

I will give a brief report on the research to your child's school at the end of the project, and you are welcome to see this. I will not identify the school, teacher or any students in any reports of the research.

This study has received ethics clearance through the University of Oxford's ethical approval process for research involving human participants, as well as from the Western Cape Education Department.

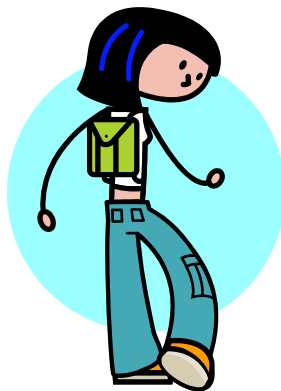


What do you do now?

If for any reason you do not want your child to be included in the research, please send me an email stating this with your child's school and name and I shall not contact you again. You can also withdraw your child from the research at any stage.

If you would like to ask any questions about the project before or during the study, please contact me. I will be happy to talk with you in more detail.

Contact details:



Thank you for your help.

Appendix 6: Ethical clearances

[Click here to go back to text]



Directorate: Research

Audrey.wyngaard@westerncape.gov.za

tel: +27 021 467 9272

Fax: 0865902282

Private Bag x9114, Cape Town, 8000

wced.wcape.gov.za

REFERENCE: 20171101-6410

ENQUIRIES: Dr A T Wyngaard



RESEARCH PROPOSAL: AN EXPLORATION INTO GENDER AND SOCIOCULTURAL DIFFERENCES WITHIN THE WORKED-EXAMPLE EFFECT IN SECONDARY SCHOOL MATHEMATICS CLASSROOMS

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **23 January 2018 till 22 June 2018**
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December).
7. Should you wish to extend the period of your survey, please contact Dr A.T Wyngaard at the contact numbers above quoting the reference number?
8. A photocopy of this letter is submitted to the principal where the intended research is to be conducted.
9. Your research will be limited to the list of schools as forwarded to the Western Cape Education Department.
10. A brief summary of the content, findings and recommendations is provided to the Director: Research Services.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

**The Director: Research Services
Western Cape Education Department
Private Bag X9114
CAPE TOWN
8000**

We wish you success in your research.

Kind regards.

Signed: Dr Audrey T Wyngaard

Directorate: Research

DATE: 02 November 2017

Lower Parliament Street, Cape Town, 8001
tel: +27 21 467 9272 fax: 0865902282
Safe Schools: 0800 45 46 47

Private Bag X9114, Cape Town, 8000
Employment and salary enquiries: 0861 92 33 22
www.westerncape.gov.za

Application Approval: ED-C1A-17-034

Title: The Worked-Example Effect: An Exploration into Gender and Socioeconomic Differences of Grade 9 Mathematics Students in Two South African Schools.

Researchers: 

The above application has been considered on behalf of the Departmental Research Ethics Committee (DREC) in accordance with the procedures laid down by the University for ethical approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to DREC, the proposed research has been judged as meeting appropriate ethical standards, and accordingly, approval has been granted.

Please note that CUREC approval does not guarantee access to participants, and it is your responsibility to check whether countries or contexts in which you plan to conduct your research might impose additional requirements.

If your research involves participants whose ability to give free and informed consent is in question (this includes those under 18 and vulnerable adults), then it is advisable to read the following NSPCC professional reporting requirements for cases of suspected abuse:

<http://www.nspcc.org.uk/globalassets/documents/information-service/factsheet-child-abuse-reporting-requirements-professionals.pdf>

Should there be any subsequent changes to the project which raise ethical issues not covered in the original application you should submit details to research.office@education.ox.ac.uk for consideration.

Good luck with your research study.

Yours sincerely,

Heath Rose

Associate Professor of Applied Linguistics

Department of Education

University of Oxford

15 Norham Gardens

Oxford, OX2 6PY

United Kingdom

Appendix 7: Student performance in Stage 5 according to Quartile

[\[Click here to go back to text\]](#)

School A:

PKL		Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	Male	71%	57%	71%	86%	0%	14%	14%
	Female	100%	62%	69%	69%	46%	8%	0%
2	Male	100%	78%	33%	33%	33%	22%	44%
	Female	82%	77%	64%	68%	45%	45%	36%
3	Male	100%	68%	92%	72%	48%	48%	52%
	Female	100%	76%	71%	82%	65%	53%	41%

School B:

PKL		Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	Male	100%	30%	40%	20%	60%	30%	0%
	Female	93%	64%	57%	36%	93%	43%	0%
2	Male	96%	72%	68%	44%	84%	52%	0%
	Female	100%	52%	62%	57%	81%	62%	0%
3	Male	100%	67%	50%	50%	83%	67%	0%
	Female	100%	75%	83%	75%	83%	58%	0%

Appendix 8: Indication of home language from Stage 2, School B

[\[Click here to go back to text\]](#)

School B		What language do you speak at home?					Students absent
		English	Afrikaans	Xhosa	Other		
PKL1	Male	1	0	8	0		8
	Female	0	0	11	0		0
PKL2	Male	1	0	24	0		3
	Female	2	1	17	1		1
PKL3	Male	0	0	6	0		0
	Female	1	0	10	0		1