Providing working memory support to anxious students using cognitive load theory compliant instructions

Deborah Chadwick
University of Wollongong

Follow this and additional works at: https://ro.uow.edu.au/theses1

Recommended Citation
PROVIDING WORKING MEMORY SUPPORT TO ANXIOUS STUDENTS USING COGNITIVE LOAD THEORY COMPLIANT INSTRUCTIONS

A thesis submitted in fulfilment of the requirements for the award of the degree

DOCTOR OF PHILOSOPHY

from

UNIVERSITY OF WOLLONGONG

by

DEBORAH CHADWICK (BSc, DipEd, MEd)

FACULTY
Social Sciences
ACADEMIC UNIT
Education

May 2018
DECLARATION

I, Deborah Chadwick, declare that this thesis, submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in the Faculty of Education, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other institution.

Deborah Chadwick

May 2018
ACKNOWLEDGEMENTS

There are a number of people who have contributed to the completion of this thesis. Such a feat cannot be achieved without the assistance of others.

Firstly, I would like to acknowledge this research has been conducted with the support of the Australian government research training program scholarship. I would like to thank my Principal Supervisor, A/Prof Shirley Agostinho, Co-supervisor, Dr Sharon Tindall-Ford, Associate Supervisor, Prof Fred Paas and Emeritus Prof Jan Wright. Their contribution of the completion of this thesis is greatly appreciated.

I would like to mention special thanks to Susan whose strong words of encouragement have stayed with me and inspired me to keep going. I am grateful also to my wonderful parents, Jules and Ash, for their assistance with marking, coffee breaks and ongoing belief I could do it! My family has tirelessly supported and encouraged me to achieve my goal. Completion of a PhD is certainly a team effort. We have lived and breathed every moment of this ride together and I am extremely grateful for their patience and understanding. This commitment has required sacrifice by everyone throughout my candidature – I would especially like to thank Nick for reminding me of the need for persistence in order to achieve my goal. The fact that I have been enrolled at university at the same time as my children, Isabella and Angus, shows it’s never too late. I hope a love of learning will encourage them to pursue their dreams.
ABSTRACT

Learning mathematics has been identified as a significant source of anxiety for many students. This anxiety places a burden on working memory, which is additional to the cognitive load associated with the learning task. Cognitive Load Theory (CLT) has informed empirically derived design principles for instructional materials that provide optimal learning support through consideration of human cognitive architecture. Worked examples are one instructional technique proposed by CLT to reduce load on working memory and support learner engagement. The assumption in this study, in the domain of mathematics, is that task complexity and the burden on working memory while completing mathematics tasks is likely to contribute to high levels of mathematics anxiety. However, there has been little research to date that investigates the relationship between CLT and affective aspects of learning such as anxiety. The focus for this thesis was to investigate whether instructional materials designed in accordance with CLT principles, specifically incorporating worked examples, could assist learners with high maths anxiety. As worked examples are an instructional technique to make efficient use of limited working memory, it is contended their application could reduce the anxiety of mathematics learners during maths instruction.

Three experiments were conducted to explore this proposition. These experiments examined learner performance, cognitive load and learner anxiety for tasks of varying levels of element interactivity. In each of the three experiments, participants were assigned to conditions using instructional materials that were designed in accordance with CLT principles (Condition 1) or were non-compliant with the principles of CLT (Condition 2). Participants were from both secondary and tertiary education settings.

In summary, there was three key findings from this research. Firstly, this study found that participants who reported high mathematics anxiety reported higher cognitive load than participants who reported low mathematics anxiety. Secondly, participants with high mathematics anxiety in Condition 1 achieved higher performance scores, experienced lower cognitive load and experienced lower levels of anxiety than participants with high mathematics anxiety in Condition 2. Finally, CLT has previously attested the effect of working memory capacity overload being restricted only to the
learning of complex tasks, that is, tasks high in element interactivity. In this study, the worked example effect was also evident for participants who reported high mathematics anxiety students when solving tasks of low element interactivity. This was due to the additional load on working memory resulting from anxiety.

This study thus confirmed that instructional materials designed in accordance with Cognitive Load Theory principles can offer support for students with high maths anxiety. The three experiments in this study were limited to algebra content within the domain of mathematics and future research could investigate these findings in other areas of learning. This research advances understanding of how mathematics instruction can be designed to support anxious students so as to facilitate reaching their full potential in learning mathematics content. Teachers should consider the inclusion of worked examples in mathematics instructional materials for highly anxious learners. This research extends cognitive load theory by investigating the effective instructional design of both simple and complex tasks, and has shown there is a link between working memory and affective aspects of a learner. These findings suggest Cognitive Load Theory may provide instructional guidelines to support highly anxious learners by providing working memory support, and this necessitates further research.
TABLE OF CONTENTS

DECLARATION........................................................................................................ii
ACKNOWLEDGEMENTS........................................................................................iii
ABSTRACT..............................................................................................................iii
TABLE OF CONTENTS........................................................................................v
LIST OF TABLES..................................................................................................xiv
LIST OF FIGURES...............................................................................................xv

1 INTRODUCTION..........................................................................................................1

1.1 Anxiety And Performance................................................................................1
1.2 Cognitive Load Theory.....................................................................................3
1.3 Purpose Of The Study.......................................................................................5
1.4 Research Questions / Hypotheses....................................................................6
1.5 Research Methodology....................................................................................10
1.6 Importance Of The Study................................................................................12
1.7 Definition Of Terms.......................................................................................13
1.8 Thesis Outline...............................................................................................17

2 REVIEW OF LITERATURE.........................................................................................19

2.1 Cognitive Load Theory and Instructional Design............................................19
   2.1.1 Human Cognitive Architecture...............................................................19
   2.1.2 Cognitive Load Theory and Working Memory.......................................22
   2.1.3 Cognitive Load Theory and Learning...................................................23
   2.1.4 Types of Cognitive Load.........................................................................24
      2.1.4.1 Extraneous Cognitive Load..........................................................24
      2.1.4.2 Intrinsic Cognitive Load...............................................................25
      2.1.4.3 Germane Cognitive Load..............................................................26
   2.1.5 Cognitive Load Effects.............................................................................28
      2.1.5.1 The Worked Example Effect........................................................28
      2.1.5.2 The Element Interactivity Effect..................................................31
2.1.5.3 The Expertise Reversal Effect ...........................................................31
2.1.5.4 The Split Attention Effect .................................................................32
2.1.5.5 The Redundancy Effect .....................................................................32
2.1.6 Measurement of Cognitive Load ..........................................................33
2.1.7 Summary of Cognitive Load Effects ......................................................36
2.2 Anxiety ....................................................................................................36
  2.2.1 Introduction ..........................................................................................36
  2.2.2 Anxiety and Working Memory ...............................................................38
  2.2.3 Anxiety and Mathematics ....................................................................40
    2.2.3.1 Student Anxiety .............................................................................40
    2.2.3.2 Teacher Anxiety ............................................................................42
  2.2.4 Measurement of Anxiety ......................................................................43
2.3 Cognitive Load Theory and Emotion .......................................................46
  2.3.1 Cognitive Load Theory and “Negative” Emotion ....................................47
  2.3.2 Cognitive Load Theory and Anxiety ......................................................48
2.4 Conclusion ..............................................................................................49

3 RESEARCH METHODOLOGY ....................................................................51

  3.1 Introduction to Experiments ....................................................................51
  3.2 Research Design ......................................................................................51
    3.2.1 Between Subjects Experimental Design ..............................................51
    3.2.2 Data Collection ..................................................................................53
    3.2.3 Data Analysis ....................................................................................56
  3.3 Summary of Research Design ..................................................................56

4 EXPERIMENT 1 ..........................................................................................58

  4.1 Introduction ..............................................................................................58
  4.2 Methodology ............................................................................................61
    4.2.1 Research Design ...............................................................................61
    4.2.2 Participants .......................................................................................63
    4.2.3 Instructional Materials ......................................................................64
4.2.4 Experimental Materials.................................................................67
4.2.5 Procedure......................................................................................72

4.3 Data Analysis..................................................................................74
4.3.1 Preliminary Analysis........................................................................74
4.3.2 Analysis of Dependent Variables......................................................81

4.4 Results............................................................................................82
4.4.1 Part 1 – Performance and Cognitive Load across Instructional
   Conditions.............................................................................................83
   4.4.1.1 Performance across Instructional Conditions...............................83
   4.4.1.2 Cognitive Load across Instructional Conditions............................84
     4.4.1.2.1 Subjective Mental Effort Rating using the CLSRS.............84
     4.4.1.2.2 Subjective ECL Rating using the CLDS..............................86
   4.4.1.3 Summary of Part 1 Results.........................................................88
   4.4.1.4 Additional Findings for Validation of Materials.........................88
4.4.2 Part 2 – Relationship between Cognitive Load and Baseline
   Mathematics Anxiety...........................................................................90
4.4.3 Part 3 – Analysis incorporating Instructional Conditions
   and Participant Anxiety.........................................................................93
   4.4.3.1 Performance..............................................................................93
     4.4.3.1.1 Additional Findings for Performance Results.......................94
   4.4.3.2 Extraneous Cognitive Load.......................................................96
     4.4.3.2.1 Subjective Mental Effort Rating using the CLSRS..........96
     4.4.3.2.2 Subjective ECL Rating using the CLDS.........................98
     4.4.3.2.3 Additional Findings for Mental Effort and ECL..........100
   4.4.3.3 Intrinsic and Germane Cognitive Load..................................101
     4.4.3.3.1 Intrinsic Cognitive Load...................................................102
     4.4.3.3.2 Germane Cognitive Load..................................................103
   4.4.3.4 Perceived Task Anxiety Ratings..............................................104
     4.4.3.4.1 Additional Findings – Perceived Task Anxiety
     and Expertise.....................................................................................107

4.5 Discussion.......................................................................................107
4.5.1 Performance and Cognitive Load across Instructional Conditions109
4.5.2 Cognitive Load and Baseline Maths Anxiety.................................110
4.5.3 Problem Solving Performance.......................................................111
4.5.4 Extraneous Cognitive Load..............................................................112
4.5.5 Intrinsic and Germane Cognitive Load..............................................116
4.5.6 Perceived Task Anxiety Ratings..........................................................118
4.5.7 Summary of Results...........................................................................120

4.6 Limitations..............................................................................................121

4.7 Conclusion..............................................................................................123

5 EXPERIMENT 2...............................................................................................124

5.1 Introduction..............................................................................................124

5.2 Methodology.............................................................................................125
  5.2.1 Research Design..................................................................................125
  5.2.2 Participants...........................................................................................127
  5.2.3 Instructional Materials.........................................................................128
  5.2.4 Experimental Materials.......................................................................131
  5.2.5 Procedure.............................................................................................134

5.3 Data Analysis............................................................................................136
  5.3.1 Preliminary Analysis............................................................................136
  5.3.2 Analysis of Dependent Variables........................................................139

5.4 Results.......................................................................................................140
  5.4.1 Part 1 – Performance and Cognitive Load across Instructional
          Conditions...............................................................................................141
    5.4.1.1 Performance across Instructional Conditions...................................141
    5.4.1.2 Cognitive Load across Instructional Conditions............................143
      5.4.1.2.1 Subjective Mental Effort Rating using the CLSRS.................143
      5.4.1.2.2 Subjective ECL Rating using the CLDS.................................145
    5.4.1.3 Summary of Part 1 Results.............................................................147
    5.4.1.4 Additional Findings for Validation of Materials............................148
  5.4.2 Part 2 – Relationship between Cognitive Load and Baseline
          Mathematics Anxiety..............................................................................150
  5.4.3 Part 3 – Analysis incorporating Instructional Conditions
          and Participant Anxiety...........................................................................154

viii
6.3.1 Preliminary Analysis.................................................................204
6.3.2 Analysis of Dependent Variables.............................................207

6.4 Results..........................................................................................209

6.4.1 Part 1 – Performance and Cognitive Load across Instructional Conditions.................................................................210
  6.4.1.1 Performance across Instructional Conditions.........................210
  6.4.1.2 Cognitive Load across Instructional Conditions......................211
    6.4.1.2.1 Subjective Mental Effort Rating using the CLSRS............212
    6.4.1.2.2 Subjective ECL Rating using the CLDS.........................213
  6.4.1.3 Summary of Part 1 Results...............................................214
  6.4.1.4 Additional Findings for Validation of Materials......................215

6.4.2 Part 2 – Relationship between Cognitive Load and Baseline Mathematics Anxiety.........................................................217

6.4.3 Part 3 – Analysis incorporating Instructional Conditions and Participant Anxiety.................................................................220

6.4.3.1 Performance............................................................................220
6.4.3.2 Extraneous Cognitive Load..................................................221
  6.4.3.2.1 Subjective Mental Effort Rating using the CLSRS............222
  6.4.3.2.2 Subjective ECL Rating using the CLDS.........................223
  6.4.3.2.3 Additional Findings for Mental Effort..............................225
6.4.3.3 Intrinsic and germane Cognitive Load.................................226
  6.4.3.3.1 Intrinsic Cognitive Load..............................................227
  6.4.3.3.2 Germane Cognitive Load..............................................228
  6.4.3.3.3 Additional Findings for GCL.........................................231
6.4.3.4 Perceived Task Anxiety Ratings...........................................232
6.4.3.5 High Anxiety and Cognitive Load of Tasks with Low Element Interactivity.................................................................234

6.5 Discussion.....................................................................................236

6.5.1 Performance and Cognitive Load across Instructional Conditions237
6.5.2 Cognitive Load and Baseline Maths Anxiety............................238
6.5.3 Problem Solving Performance..................................................239
6.5.4 Extraneous Cognitive Load......................................................240
6.5.5 Intrinsic and Germane Cognitive Load.....................................242
6.5.6 Perceived Task Anxiety Ratings .........................................................244
6.5.7 High Anxiety and Cognitive Load of Tasks with Low Element Interactivity .......................................................246
6.5.8 Summary of Results ........................................................................247

6.6 Limitations ..........................................................................................249
6.7 Conclusion ..........................................................................................249

7 DISCUSSION ..........................................................................................250

7.1 Introduction ..........................................................................................250
7.2 Summary of Results ..............................................................................253
  7.2.1 Summary of Results for Research Questions ....................................253
    7.2.1.1 Performance and Cognitive Load using CLT compliant Instructional Materials ............................................256
    7.2.1.2 Relationship between Cognitive Load and Maths Anxiety .................................................................256
    7.2.1.3 Performance of High Anxiety Learners: High Element Interactivity .................................................................257
    7.2.1.4 Extraneous Cognitive Load of High Anxiety Learners: High Element Interactivity ............................................258
    7.2.1.5 Performance and Cognitive Load of High Anxiety Learners: Low Element Interactivity ....................................259
  7.2.2 Summary of Results for Exploratory Questions ....................................259
    7.2.2.1 ICL of High Anxiety Learners .........................................................260
    7.2.2.2 GCL of High Anxiety Learners .........................................................261
    7.2.2.3 Task Anxiety of High Anxiety Learners ...........................................262
  7.3 Summary of Key Findings .....................................................................263
    7.3.1 Relationship between Cognitive Load and Maths Anxiety ..........263
    7.3.2 CLT compliant Instructional Materials Provided Working Memory Support for Anxious Learners ......................264
      7.3.2.1 Performance .................................................................264
      7.3.2.2 Extraneous Cognitive Load .........................................................265
      7.3.2.3 Perception of Intrinsic Cognitive Load ...........................................265
      7.3.2.4 Investment of Germane Resources ..............................................266
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3.2.5 Task Anxiety</td>
<td>266</td>
</tr>
<tr>
<td>7.3.3 CLT Effects Evident for Highly Anxious Learners Solving</td>
<td>267</td>
</tr>
<tr>
<td>Tasks of Low Element Interactivity</td>
<td></td>
</tr>
<tr>
<td>7.4 Limitations of Current Research</td>
<td>268</td>
</tr>
<tr>
<td>7.5 Theoretical Implications for CLT</td>
<td>269</td>
</tr>
<tr>
<td>7.6 Practical Implications of the Study</td>
<td>270</td>
</tr>
<tr>
<td>7.6.1 Mathematics Instruction</td>
<td>270</td>
</tr>
<tr>
<td>7.6.2 Teacher Anxiety</td>
<td>271</td>
</tr>
<tr>
<td>7.6.3 Summary of Practical Implications</td>
<td>271</td>
</tr>
<tr>
<td>7.7 Ideas for Future Research</td>
<td>272</td>
</tr>
<tr>
<td>7.8 Conclusion</td>
<td>274</td>
</tr>
<tr>
<td>8 REFERENCES</td>
<td>275</td>
</tr>
<tr>
<td>9 REFERENCES EMERGING FROM THIS RESEARCH</td>
<td>295</td>
</tr>
<tr>
<td>10 APPENDIX</td>
<td>296</td>
</tr>
<tr>
<td>A1 Ethics Approval Notification</td>
<td>296</td>
</tr>
<tr>
<td>A2 Ethics Approval Renewal</td>
<td>298</td>
</tr>
<tr>
<td>B Instructional Materials For CLT Compliant Condition</td>
<td>300</td>
</tr>
<tr>
<td>(Experiment 1)</td>
<td></td>
</tr>
<tr>
<td>C Instructional Materials For CLT Non-Compliant Condition</td>
<td>328</td>
</tr>
<tr>
<td>(Experiment 1)</td>
<td></td>
</tr>
<tr>
<td>D Product-Oriented Worked Example Sheet For CLT Non-Compliant Condition</td>
<td>350</td>
</tr>
<tr>
<td>(Experiment 1)</td>
<td></td>
</tr>
<tr>
<td>E Permission To Use Instruments Correspondence</td>
<td>352</td>
</tr>
<tr>
<td>F Consent Form (Experiment 1)</td>
<td>357</td>
</tr>
<tr>
<td>G Participant Information Sheets (Experiment 1)</td>
<td>360</td>
</tr>
<tr>
<td>H Teacher Information Sheet (Experiment 1)</td>
<td>365</td>
</tr>
<tr>
<td>I Instructions To Teachers (Experiment 1)</td>
<td>367</td>
</tr>
<tr>
<td>J Additional Descriptive Statistics And Additional Findings</td>
<td>369</td>
</tr>
<tr>
<td>(Experiment 1)</td>
<td></td>
</tr>
</tbody>
</table>
K  Instructional Materials For CLT Compliant Condition
   (Experiment 2)........................................................................................................377
L  Instructional Materials For CLT Non-Compliant Condition
   (Experiment 2)........................................................................................................411
M  Product-Oriented Worked Example Sheet For CLT Non-
   Compliant Condition (Experiment 2).................................................................437
N  Consent Form (Experiment 2)...............................................................................439
O  Participant Information Sheet (Experiment 2).......................................................442
P  Additional Descriptive Statistics And Additional Findings
   (Experiment 2)........................................................................................................445
Q  Ethics Approval Amendment..................................................................................452
R  Abbreviated Maths Anxiety Scale (Experiment 3)...............................................454
S  Instructional Materials For CLT Compliant Condition
   (Experiment 3).........................................................................................................458
T  Instructional Materials For CLT Non-Compliant Condition
   (Experiment 3).........................................................................................................480
U  Consent Form (Experiment 3)................................................................................497
V  Participant Information Sheets (Experiment 3).....................................................500
W  Teacher Information Sheet (Experiment 3)..........................................................505
X  Instructions To Teachers (Experiment 3)............................................................507
Y  Additional Descriptive Statistics And Additional Findings
   (Experiment 3).........................................................................................................509
LIST OF TABLES

Table 3.1  Instruments Used for Measurement of Variables  53
Table 4.1  Normality of Data Under Each Condition  76
Table 4.2  Baseline AMAS Scores for Participants in Each Condition Identifying Upper and Lower Terciles  80
Table 4.3  Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Condition  83
Table 4.4  Descriptive Statistics – Mental Effort Rating (CLSRS) for CLT compliant and CLT non-compliant Condition  85
Table 4.5  Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Condition  87
Table 4.6  Means, Standard Deviations and Effect Sizes for Cognitive Load Ratings  91
Table 4.7  Correlation between Cognitive Load Measures and Participants’ AMAS Score  92
Table 4.8  Descriptive Statistics – Performance with Anxiety Groupings  94
Table 4.9  Descriptive Statistics – Mental Effort Rating (CLSRS) with Anxiety Groupings  96
Table 4.10  Descriptive Statistics – Extraneous Cognitive Load with Anxiety Groupings  98
Table 4.11  Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings  102
Table 4.12  Descriptive Statistics – Germane Cognitive Load with Anxiety Groupings  103
Table 4.13  Descriptive Statistics – Perceived Task Anxiety with Anxiety Groupings  105
Table 5.1  Baseline AMAS Scores for Participants in Each Condition Identifying Upper and Lower Terciles  138
Table 5.2  Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Condition  141
Table 5.3 Descriptive Statistics – Mental Effort Rating (CLSRS) for CLT compliant and CLT non-compliant Condition

Table 5.4 Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Condition

Table 5.5 Means, Standard Deviations and Effect Sizes for Cognitive Load Ratings

Table 5.6 Correlation between Cognitive Load Measures and Participants’ AMAS Score

Table 5.7 Significant Results from T-Tests Comparing Participants’ Baseline Anxiety and Instructional Conditions

Table 5.8 Descriptive Statistics – Performance with Anxiety Groupings

Table 5.9 Descriptive Statistics – Mental Effort Rating (CLSRS) with Anxiety Groupings

Table 5.10 Descriptive Statistics – Extraneous Cognitive Load with Anxiety Groupings

Table 5.11 T-Tests for Task Difficulty for Each Group

Table 5.12 Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings

Table 5.13 T-Tests showing Significant Differences in ICL for Low and High Anxiety Groups in Each Instructional Condition

Table 5.14 Descriptive Statistics – Germane Cognitive Load with Anxiety Groupings

Table 5.15 Significant Difference in GCL for CNLA Group Compared to CNHA and CCLA Groups

Table 5.16 Descriptive Statistics – Perceived Task Anxiety with Anxiety Groupings

Table 6.1 Baseline AMAS Scores for Participants in Each Condition Identifying Upper and Lower Terciles

Table 6.2 Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Condition

Table 6.3 Descriptive Statistics – Mental Effort Rating (CLSRS) for CLT compliant and CLT non-compliant Condition
Table 6.4  Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Condition  213
Table 6.5  Means, Standard Deviations and Effect Sizes for Cognitive Load Ratings  217
Table 6.6  Correlation between Cognitive Load Measures and Participants’ AMAS Score  218
Table 6.7  Descriptive Statistics – Performance with Anxiety Groupings  221
Table 6.8  Descriptive Statistics – Mental Effort Rating (CLSRS) with Anxiety Groupings  222
Table 6.9  Descriptive Statistics – Extraneous Cognitive Load with Anxiety Groupings  224
Table 6.10  Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings  227
Table 6.11  Descriptive Statistics – Germane Cognitive Load with Anxiety Groupings  229
Table 6.12  Descriptive Statistics – Perceived Task Anxiety with Anxiety Groupings  232
Table 7.1  Summary of Findings: Research Questions and Hypotheses for Experiments 1, 2 and 3  254
Table 7.2  Summary of Findings: Exploratory Questions for Experiments 1, 2 and 3  260
LIST OF FIGURES

Figure 2.1  Working Memory Structure  21
Figure 2.2  An example of how varying conditions of instructional design / format and task difficulty for anxious students can impact working memory capacity  27
Figure 2.3  The Yerkes-Dodson Law  37
Figure 2.4  Factor Loadings of retained AMAS items  45
Figure 2.5  Correlations among self report Anxiety Assessment instruments  45
Figure 4.1  Sample worked example and problem to solve of low element interactivity from CLT compliant instructional materials  65
Figure 4.2  Sample problem to solve of low element interactivity from CLT non-compliant instructional materials  66
Figure 4.3  A sample of a non-paired product-oriented worked example from the separate A4 sheet accompanying CLT non-compliant instructional materials  66
Figure 4.4  Frequency polygon representing normal distribution of AMAS scores in both instructional design conditions  75
Figure 4.5  Organisation of participants into four groups for Part 3 of data analysis  77
Figure 4.6  Germane cognitive load for CLT compliant and CLT non-compliant conditions  89
Figure 4.7  Graph of mean performance scores for experimental groups  95
Figure 4.8  Graph of mental effort ratings for experimental groups  97
Figure 4.9  Graph of extraneous cognitive load for experimental groups  99
Figure 4.10  Graph of germane cognitive load for experimental groups  103
Figure 4.11  Graph of perceived task anxiety for each experimental group  106
Figure 5.1  Sample worked example and problem to solve of low element interactivity from CLT compliant instructional materials  129
Figure 5.2  Sample problem to solve of low element interactivity from CLT non-compliant instructional materials  130
Figure 5.3  A sample of a non-paired product-oriented worked example from the separate A4 sheet accompanying CLT non-compliant instructional materials

Figure 5.4  Graph of extraneous cognitive load for CLT compliant condition and CLT non-compliant condition

Figure 5.5  Germane cognitive load for CLT compliant and CLT non-compliant condition

Figure 5.6  Graph of mean performance scores for experimental groups

Figure 5.7  Graph of mental effort ratings for experimental groups

Figure 5.8  Graph of extraneous cognitive load for experimental groups

Figure 5.9  Graph of germane cognitive load for experimental groups

Figure 5.10  Graph of perceived task anxiety for experimental groups

Figure 6.1  Sample worked example and problem to solve of low element interactivity from CLT compliant instructional materials

Figure 6.2  Sample problem to solve of low element interactivity from CLT non-compliant instructional materials

Figure 6.3  Process to identify participants in each condition

Figure 6.4  Germane cognitive load for CLT compliant and CLT non-compliant conditions

Figure 6.5  Graph of mental effort ratings for experimental groups

Figure 6.6  Graph of extraneous cognitive load for experimental groups

Figure 6.7  Graph of intrinsic cognitive load for experimental groups

Figure 6.8  Graph of germane cognitive load for experimental groups

Figure 6.9  Graph of perceived task anxiety for experimental groups
1 INTRODUCTION

Over numerous years of experience as a classroom teacher of mathematics I have observed how the learning and performance of many of my students have been impeded by their high levels of anxiety when asked to perform mathematical tasks. My own observations are supported by a considerable body of research that has demonstrated how elevated levels of anxiety are particularly prevalent within mathematics learning environments (Hopko, McNeil, Lejuez, Ashcraft, Eifert & Riel, 2003b; Richardson & Suinn, 1972; Richardson & Woolfolk, 1980; Tobias, 1981). Research thus far has provided few directions for addressing this issue, with the focus primarily being on intervention techniques designed to distract students from their anxiety rather than focus on the sources of this mathematics anxiety. This study will address this gap in the research by utilising cognitive load theory to design a study investigating the efficacy of instructional design as a means to improve performance and alleviate anxiety in mathematics.

1.1 ANXIETY AND PERFORMANCE

From a psychological perspective, anxiety is a multifaceted response to a perceived threat, which involves psychological, physiological and behavioural changes (Borkovec, Weerts, & Bernstein, 1977). These changes are dependent on both the individual (e.g. the learner) and specific conditions or states (Sarason, 1978). (e.g. mathematics tasks). Research demonstrates a significant and positive correlation between maths anxiety and general anxiety (Hembree, 1990) and between maths anxiety and test anxiety (Alexander & Martray, 1989). However, Hunt (2011) emphasises the need to identify maths anxiety as a “distinctly separate construct” (p. 9), and this study regards it as such by measuring maths anxiety using a scale specifically designed for this purpose.

From a cognitive perspective, the relationship between anxiety and performance has been explained in terms of the fewer working memory resources available to highly anxious learners (Eysenck & Payne, 2006). Research has demonstrated how anxiety reduces working memory (WM) capacity as a result of cognitive resources being allocated to and dominated by intrusive anxiety-related thoughts (Darke, 1988a;
Eysenck, 1985; Hopko et al., 2003b), which in turn have deleterious effects on many aspects of learning, including performance, error rates and response times.

A number of anxiety intervention techniques have been investigated to help students manage anxiety. These include eye movement desensitisation and reprocessing (EMDR), which involves the induction of eye movement during the recall of unpleasant memories in order to reduce their emotional intensity; the use of verbal shadowing, where attention allocated to a simple auditory recording reduces distressing memories; and the use of copying a complex figure as a distractor while thinking about aversive memories (Gunter & Bodner, 2008). Anxiety intervention techniques have also included the use of brief expressive writing tasks immediately prior to an important exam to reduce intrusive thoughts (Ramirez & Beilock, 2011); and complex counting tasks which divide attention and interfere with anxious thoughts (van den Hout, Engelhard, Smeets, Hornsveld, Hoogeveen, de Heer, Toffolo & Rijkeboer, 2010). These interventions are intended to distract learners from the task irrelevant thoughts associated with anxiety and therefore assist learners in directing their attention to the learning task. However, these distractions may be somewhat counter-productive by involving tasks that use the limited WM resources that are already compromised by high anxiety. In addition, effectively masking anxiety with the provision of such distractions does not actually eliminate the underlying anxiety that accompanies mathematics instruction for highly anxious learners.

An alternative approach is that made available by cognitive load theory (CLT). CLT has been used to design instructional materials to reduce load on working memory. Reducing the load on working memory increases the capacity to cognitively engage with the learning materials. Worked examples are one instructional technique to reduce load on working memory and facilitate learning (Ward & Sweller, 1990; Paas, Tuovinen, Tabbers & van Gerven, 2003b). In the context of mathematics, the assumption in this study is that task complexity and the burden on working memory while completing mathematics tasks is likely to contribute to high levels of mathematics anxiety. It follows that the provision of mathematics instructional materials designed in accordance with the principles of CLT, one such principle being worked examples, is likely to provide the means to enhance learning and as a consequence, has the potential
to reduce the anxiety of mathematics learners during maths instruction. It is this assumption that will be tested in this study.

1.2 COGNITIVE LOAD THEORY

Knowledge of human cognitive architecture has established WM to be limited in capacity (Baddeley & Hitch, 1974). The limitations associated with the finite capacity of WM have been extensively investigated in terms of CLT (Paas & Sweller, 2012; Sweller, 1988; Sweller, van Merriënboer & Paas, 1998). CLT scholars argue that it is crucial that sufficient WM resources be available for learning and as such, ensure WM resources are not misused, or “wasted”, on thoughts or activities that do not contribute to learning. Cognitive load theory (CLT) provides an evidence base of design principles to optimise limited WM capacity (Chandler & Sweller, 1991). Instructional formats aligned with the principles of CLT result in improved processing ability for a learner during instruction (Eysenck & Clavo, 1992). Much of the research on CLT to date has focussed only on the impact of cognitive load on a learner’s performance, in terms of (among other factors) instructional design, element interactivity and expertise. There has been little research that has investigated the relationship between CLT and affective aspects of learning such as anxiety. One of the main contributions of the research described in this thesis is to address this gap by an investigation of the influence of mathematics anxiety on learning and the efficacy of CLT compliant instructions in alleviating this anxiety and thereby enhancing performance and facilitating learning.

Traditionally, many instructional resources are designed without consideration of the limitations of WM and the effects of a high cognitive load on WM. Highly anxious learners experience a diminished WM capacity and poorly designed instructional materials increase the cognitive load associated with a task (Ashcraft & Kirk, 2001). High cognitive load is of particular importance for highly anxious learners already experiencing a reduction in available WM resources due to the anxiety (Darke, 1988a; Eysenck, 1985). For highly anxious learners, anxiety associated with solving maths tasks results in less WM resources available for learning and may create overload in WM. This would ultimately impact learning in mathematics, resulting in poor performance, increased anxiety and decreased learning efficiency. Therefore,
identifying instructional strategies that support anxious learners is essential if mathematics performance is to be improved. Improved performance may, in turn, lead to a reduction in anxiety by the learner, reflected in anxiety ratings following completion of a task.

CLT provides instructional design guidelines that can be used to structure instructional materials in order to enhance learning by reducing the extraneous cognitive load of a task (Chandler & Sweller, 1991; Mayer, 1997; Mayer & Moreno, 1999; Sweller et al., 1998; van Merriënboer & Kester, 2005). When extraneous load is minimised by effective instructional design, more WM resources are available for dealing with the intrinsic load imposed on WM associated with the element interactivity of the task. Thus, the successful completion and learning of complex tasks are potentially enhanced (Kalyuga, 2011). Furthermore, this allows for a greater investment of germane resources that may enhance learning. In the absence of reduced extraneous cognitive load, WM would be unable to accommodate the additional germane load. This study attends to these issues through an investigation of the different types of cognitive load associated with mathematics tasks for highly anxious learners.

From a CLT perspective, the complexity, or level of element interactivity, of a task determines the cognitive load imposed on working memory. Element interactivity refers to the extent to which individual elements of a task can be learnt and understood in isolation (Sweller, 2010). As element interactivity increases, individual elements cannot be understood in isolation, making the task more complex. As such, tasks with high element interactivity impose a greater load on WM due to the simultaneous processing of a number of elements. Consequently, instructional design becomes critical for complex tasks (Pollock, Chandler & Sweller, 2002; Sweller et al., 1998). Effective instructional design will ensure the load on WM does not exceed WM capacity. Thus far, CLT research has shown that instructional materials based on CLT design principles are beneficial in optimising WM resources only when task complexity or element interactivity is high. CLT has assumed the key factor determining the cognitive load associated with a task is related to element interactivity. For tasks of low element interactivity, WM capacity has been shown to be sufficient to manage the demands of the task. CLT effects have not been found to be evident for such simple tasks (Sweller
et al., 1998; Pollock et al., 2002). Experiments 1 and 2 in this study were based on this assumption, and therefore investigated tasks of high element interactivity only.

As findings of Experiments 1 and 2 indicated that there was a relationship between cognitive load and maths anxiety for tasks of high element interactivity, it was decided that an additional focus for tasks of low element interactivity should be added in Experiment 3. WM capacity is compromised by affective attributes of the learner, such as anxiety. Given that WM resources are consumed by anxiety, it was determined these effects should be investigated for highly anxious learners when solving simple mathematics tasks, those of low element interactivity. As a consequence, in the final experiment (Experiment 3), it was decided that the research design should be adapted to examine the relationship between mathematics anxiety and cognitive load for tasks of low element interactivity, an area of research yet to be investigated in CLT.

1.3 PURPOSE OF THE STUDY

This study examined the interrelationship between a learner’s performance, cognitive load and anxiety when solving mathematical problems. This study examined whether the reduced WM load associated with CLT compliant instructional materials resulted in improved mathematics performance and reduced anxiety levels for highly anxious learners. Although research has independently shown extraneous cognitive load can be reduced by the development of CLT compliant instructional materials, and WM (and consequently learner performance) is adversely effected by anxiety (Galloway & Pope, 2007; Judge & Ilies, 2002), little attention has been given to the interaction between these factors in a given mathematics task.

As anxiety consumes WM resources, less cognitive resources are made available for a learning task. It was hypothesised that if learning materials were not designed according to the principles of CLT, the high extraneous cognitive load generated by instructional design in addition to the learner’s anxiety, would compromise learning for highly anxious individuals. The extent of the influence of one or both of these factors was investigated, with the suggestion that CLT compliant materials, which reduce extraneous cognitive load, would support learning for highly anxious individuals. In
addition, if instructional materials were designed in compliance with CLT, in this case by providing worked examples, it was investigated whether the level of anxiety experienced by learners would be reduced because of the step-by-step guidance provided to successfully complete the problem. This would result in dual benefits for highly anxious learners using CLT compliant materials: a reduced extraneous cognitive load and a reduction in anxiety, both of which consume WM resources.

The relationship between CLT and anxiety was investigated by presenting participants with CLT compliant or CLT non-compliant instructional materials with mathematical algebra tasks of low, moderate and high element interactivity. The study consisted of three experiments and examined learners’ performance, the perceived cognitive load of the task and the level of anxiety experienced.

Participants in the study were identified as highly anxious using the validated Abbreviated Mathematics Anxiety Scale (AMAS) (Hopko, Mahadevan, Bare & Hunt, 2003a). This instrument comprises 9 self-rating questions using a scale of 1 (low anxiety) to 5 (high anxiety). Scores range from 9 to 45; the higher the score, the higher the level of maths anxiety experienced by the learner. Learner profiles based on participant’s mathematics anxiety ratings (and expertise in additional analysis) were created and used to investigate the research questions posed by this study, which focussed on performance, cognitive load and anxiety with regards to the use of CLT compliant instructional materials.

1.4 RESEARCH QUESTIONS / HYPOTHESES

The study posed five research questions as well as two exploratory research questions. The first research question focussed on examining the effectiveness of CLT compliant instructional materials, in terms of performance scores and cognitive load measures, independent of consideration of mathematics anxiety. Research Question 2 looked at the potential relationship between cognitive load and mathematics anxiety. Research Questions 3 and 4 examined the effectiveness of CLT compliant instructional materials, in terms of performance scores and cognitive load measures, for learners with low and high maths anxiety. Exploratory Question 1 investigated whether high maths anxiety
impacted the perceived intrinsic and germane cognitive load associated with a complex maths task, and whether CLT compliant materials had any influence on this perception. Exploratory Question 2 examined whether CLT compliant instructional materials could effectively reduce the level of anxiety associated with solving a complex maths task. Both of these questions were exploratory as they were reliant on assumptions regarding elevated levels of maths anxiety associated with complex tasks and the effectiveness of CLT compliant materials to provide support to highly anxious learners. The final research question was specific to Experiment 3. This involved investigating whether the learning support provided by CLT compliant instructional materials for complex tasks was also beneficial for highly anxious learners when solving simple tasks. The research questions and associated alternative hypotheses, and the exploratory research questions being investigated were as follows:

RQ1: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

H₁: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

H₂: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

RQ₂: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?
H₃: Participants with high baseline mathematics anxiety will report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety.

RQ₃: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H₄: When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load and greater investment of germane resources afforded by CLT compliant instructional materials.

RQ₄: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H₅: When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials.

RQ₅: When solving problems low in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners with
high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H$_6$: When solving mathematics problems low in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will achieve higher performance scores and report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. This is due to CLT compliant instructional materials providing learning support when WM resources are expended by anxiety.

EQ$_1$: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials?

EQ$_2$: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

The rationale for the six associated hypotheses is as follows. Overall, these hypotheses suggest that for highly anxious learners, the use of CLT compliant instructional materials in mathematics is important for tasks of high element interactivity, due to the corresponding elevated cognitive load. This may be particularly relevant for highly anxious learners already experiencing a compromised WM capacity. Therefore, for complex tasks that impose a greater load on WM, methods to alleviate the burden on WM, such as CLT compliant instructional materials, may become more critical. CLT compliant instructions therefore become more important for highly anxious learners due to their already compromised WM resources.

When highly anxious learners are solving difficult tasks, those with high element interactivity, performance is compromised. When the level of element interactivity of a task is low, performance results for highly anxious learners may not be compromised as
the total load is still within WM capacity. However, CLT non-compliant mathematics instructional materials create additional extraneous cognitive load on WM. For highly anxious learners, this may have a detrimental effect on performance even for a maths task low in element interactivity.

Instructional materials designed in compliance with CLT should effectively reduce the cognitive load of the task. This is of particular importance to highly anxious learners who may experience greater cognitive load associated with a task. In addition, the use of CLT compliant instructional materials may reduce the overall anxiety experienced by highly anxious learners while completing mathematics tasks as a result of additional WM resources made available due to the improved instructional design. Furthermore, an improvement in performance and learning efficiency may improve learner satisfaction and confidence alleviating some anxiety associated with completion of the task. Conversely, the use of CLT non-compliant instructional materials leads to an increase in the extraneous load of the task. This, combined with the high intrinsic load of a complex task, may have a detrimental effect on performance and create further anxiety in an anxious learner.

1.5 RESEARCH METHODOLOGY

This study was comprised of three experiments that investigated whether instructional materials designed in accordance with CLT principles, specifically incorporating worked examples, could assist learners with high maths anxiety. This involved examination of the effectiveness of CLT compliant instructional materials in providing learning support for highly anxious learners. All three experiments examined performance scores, subjective cognitive load ratings and perceived anxiety ratings of highly anxious learners. Experiment 1 was conducted in a secondary school setting with seventy-one participants. Experiment 2 was conducted in a tertiary education setting with two hundred and fifty-two participants. Experiment 3 was conducted in a secondary school setting with ninety-two participants. In all three experiments, participants were randomly assigned to one of two conditions, CLT compliant instructional materials or CLT non-compliant instructional materials.
The study described in this thesis drew on CLT to investigate the efficacy of instructional design as a method to reduce learner anxiety and thereby support learning. The focus of this study was threefold. The first step was to establish an association between mathematics anxiety and cognitive load. Secondly, the study examined whether mathematics performance was improved and cognitive load reduced for highly anxious learners with the use of CLT compliant instructional materials. Furthermore, it examined whether there was an associated reduction in student anxiety levels whilst using CLT compliant materials, providing some relief when solving complex mathematics tasks. Finally, the original focus for this study was for mathematics problems of high element interactivity. Experiment 3 extended the analysis to tasks of both low and high element interactivity to investigate evidence of cognitive load effects for highly anxious learners when solving simple mathematics tasks.

The following analysis was undertaken for each Experiment. Preliminary analysis involved a 2 (Instructional Design) x 3 (Element Interactivity) analysis of variance (ANOVA) (Experiments 1 and 2) or a 2 (Instructional Design) x 2 (Element Interactivity) analysis of variance (ANOVA) (Experiment 3). This analysis was performed to confirm previous research associated with the effectiveness of CLT compliant instructional materials. Following initial analysis, Pearson’s correlation coefficients were calculated to determine the relationship between cognitive load and participant’s baseline anxiety.

Participants were identified as high or low anxiety to create four experimental groups – low anxiety and high anxiety in each of the two experimental conditions. Analysis of participant’s performance, reported cognitive load and anxiety ratings was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial analysis (Experiments 1 and 2) or a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2 (Element Interactivity Condition) factorial analysis (Experiment 3). Further analysis of data by means of Cohen’s $d$ and t-tests was performed to further investigate significant effects. Analysis for Experiment 1 and 2 focused on tasks of high element interactivity only. Analysis for Experiment 3 was extended to include tasks of both high and low element interactivity.
1.6 IMPORTANCE OF THE STUDY

There has been little research that has investigated the relationship between CLT and affective aspects of learning such as anxiety. This study intended to investigate the relevance of CLT in a novel context, that is, the application of materials designed in accordance with CLT as a means of support for highly anxious learners. Instructional materials designed in compliance with CLT were expected to be of particular importance to highly anxious learners due to additional burden placed on WM as a result of the anxiety experienced. CLT compliant instructional materials have been shown to reduce the extraneous cognitive load associated with a complex task (Chandler & Sweller, 1991). This may result in learning support for highly anxious learners and compensate for the load associated with high anxiety. Furthermore, CLT research has traditionally investigated benefits of optimally designed instructions with novice learners and novel content. This study was unique as it investigated the effectiveness of CLT compliant instructions in providing support for highly anxious learners of varying levels of expertise. Finally, CLT effects have traditionally been found to be present for tasks of high element interactivity only. As available WM resources are reduced when a learner experiences anxiety, this study examined whether CLT effects may also be relevant in conditions of low element interactivity for highly anxious learners.

There is an emergent need to investigate the affective characteristics of learners (Ashcraft, Krause & Hopko, 2007). A high level of anxiety in an educational domain such as mathematics obstructs learning as a result of expending WM resources on thoughts not relevant to learning. Identification of strategies that could be adopted to address anxiety associated with mathematics are needed to allow learners to maximise WM resources available to invest in a learning task. This in turn could assist educators in determining instructional techniques that could improve performance and reduce anxiety. This study demonstrated the efficacy of instructional materials designed in accordance with CLT in providing learning support for highly anxious learners. CLT instructional materials successfully reduced the cognitive load associated with a task, which in turn, enhanced performance. This occurred, at least in part, as a result of
encouraging successful allocation of resources relevant to complex learning tasks alleviating task related anxiety.

The findings therefore have both theoretical and instructional implications. By ascertaining a relationship between maths anxiety and cognitive load, the usefulness of CLT compliant instructional materials for highly anxious learners may be determined. Instructional design may contribute to mathematics anxiety and as such, designing instructional materials in compliance with CLT may alleviate some of the anxiety of highly anxious learners. These understandings may in turn improve learners’ perception of and performance in mathematics and consequently increase participation rates in mathematics. The empirical results from this study can make a theoretical contribution to CLT by demonstrating the benefits of CLT compliant instructions for students who experience high levels of anxiety in mathematics. This study may lead to the development of instructional materials and teaching strategies effective in:

1. improving the performance of anxious students in mathematics,
2. reducing student anxiety through instructional design leading to improved performance,
3. maximising and maintaining student intrinsic motivation which may influence attrition rates in mathematics,
4. providing students with strategies to assist in the efficient allocation of cognitive resources to a task to improve the effectiveness and efficiency of learning, and
5. demonstrating the importance of teacher expertise as a potential strategy to alleviate anxiety in teachers and therefore, in their students.

1.7 DEFINITION OF TERMS

The following terms will be defined as follows when used in this study:

CLT compliant (CC): Instructional materials designed according to the principles of cognitive load theory, in this case, with the provision of paired process-oriented worked examples, presented with no split attention effects.
*CLT non-compliant (CN)*: Instructional materials not designed according to the principles of cognitive load theory, in this case, with provision of product-oriented worked examples only with split attention effects (Experiment 1 and 2) or conventional problems only (Experiment 3).

*Cognitive Load Differentiating Scale (CLDS)*: A ten-item instrument for the measurement of cognitive load, with questions determining separate values for each component of cognitive load – intrinsic, extraneous and germane. Participants provide responses on an 11-point scale (Leppink, Paas, van der Vleuten, van Gog, & van Merriënboer, 2013).

*Cognitive Load Subjective Rating Scale (CLSRS)*: A 9-point scale designed for participants to report their perceived mental effort invested in a task (Paas, 1992).

*Conventional problem solving*: A problem-solving task without the provision of support and guidance for the learner (Paas, 1992). This involves the use of strategies such as means-ends analysis to progress from a given problem state to a desired goal state (Sweller, 1988).

*Efficiency*: A score for the relative efficiency of instructional conditions that is a function of performance and mental effort measures (Paas et al., 2003b).

*Element interactivity (EI)*: Determined by the number of interacting elements in a task hence whether these elements can be learned in isolation (Sweller, 2010). Element interactivity takes into consideration the nature of the information and the level of expertise of the learner, that is, the WM load created by the task.

*Experimental Group*: One of four groups into which participants were organised according to the instructional design condition and their baseline maths anxiety. Groups were CLT Compliant Low Anxiety (CCLA), CLT Compliant High Anxiety (CCHA), CLT Non-compliant Low Anxiety (CNLA) and CLT Non-compliant High Anxiety (CNHA).
**Extraneous cognitive load (ECL):** Refers to the effort required due to instructional design of the information presented to learners and the learning activities required of them (Paas et al., 2003b).

**Germane cognitive load (GCL):** Refers to the load associated with additional cognitive resources engaged by the learner on a task to further enhance learning. This load is associated with activities that support schema construction and automation (Paas et al., 2003b). Germane load is specifically composed of features associated with instructional materials that are beneficial to the learning of those materials (Leppink et al., 2013).

**High anxious mathematics learner (HA):** Identified according to a high baseline measure of anxiety on the Abbreviated Mathematics Anxiety Scale (AMAS) (Hopko et al., 2003a). These learners were in the highest tercile of scores in the pre-test phase.

**High element interactivity:** materials consist of elements with reference to other elements that must be considered simultaneously.

**Instructional Design:** Denotes organisation of learning materials, such as layout and content, for an educational setting. Instructional design conditions for this research were either CLT compliant (CC) or CLT non-compliant (CN).

**Intrinsic cognitive load (ICL):** refers to the complexity of a task determined by the level of element interactivity, which is influenced by prior knowledge, or the level of expertise of the learner. This load is independent of instructional design (Paas et al., 2003b).

**Low anxious mathematics learner (LA):** identified according to a low baseline measure of anxiety on the Abbreviated Mathematics Anxiety Scale (AMAS) (Hopko et al., 2003a). These learners were in the lowest tercile of scores in the pre-test phase.

**Low element interactivity:** Refers to simple tasks with few interacting elements, which can therefore be learned in isolation. Components of the task may be considered independently (Renkl & Atkinson, 2003).
**Mathematics Anxiety:** Unless specifically stated otherwise, refers to state anxiety, which is defined by a situational emotional response to a specific stimulus, in this case, mathematics (Spielberger, 1972). It may be considered as a general trepidation associated with mathematics (Richardson & Woolfolk, 1980), and influences an individual’s achievement and participation in mathematics (Hembree, 1990).

**Perceived Task Anxiety:** A subjective measure of anxiety related to the task reported by participants immediately following completion of each section of algebra problems.

**Process-oriented worked example:** A worked example that, in addition to the problem solution, provides the learner with an explanation as to why each step is required and appropriate for the particular problem (van Gog, Paas, van Merriënboer, 2008).

**Product-oriented worked example:** A worked example that consists of the problem statement, the steps required to complete the problem and the correct final solution (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Renkl, 1997).

**Stage five mathematics:** Syllabus for Years 9 and 10 mathematics students as outlined in NSW Education Standards Authority (2015) and Australian National Curriculum V2 (2011). Stage 5 outcomes are covered in 3 stages of increasing levels of difficulty, and include content related to working mathematically, number and algebra, measurement and geometry and, statistics and probability (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-k10/).

**Stage four mathematics:** Syllabus for Years 7 and 8 mathematics students as outlined in NSW Education Standards Authority (2015) and Australian National Curriculum V2 (2011). Stage 4 outcomes are covered in one stage, and include content related to working mathematically, number and algebra, measurement and geometry and, statistics and probability (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-k10/).

**Worked Example:** Highly structured step-by-step model demonstrating how to perform a task (Clark, Nguyen & Sweller, 2006). Worked examples effectively improve a learner’s understanding of the solution steps required to solve a problem, including how and when to employ them (Paas & van Gog, 2006).
1.8 THESIS OUTLINE

The structure of the thesis is as follows:

- Chapter one details the purpose and the importance of the study through identification of the relevant facets of the research – cognitive load theory and anxiety – and establishing key research questions and hypotheses;
- Chapter two reviews relevant literature including human cognitive architecture, working memory and cognitive load theory, specifically types of cognitive load, element interactivity and relevant cognitive load effects such as the worked example effect, the element interactivity effect, the expertise reversal effect, the split attention effect and the redundancy effect. Research surrounding the impact of anxiety in the area of mathematics instruction will be examined;
- Chapter three introduces the research design by explaining the rationale for the set of three experiments that comprises this study and provides an overview of each of the experiments;
- Chapter four presents the methodology, data analysis, results and discussion for Experiment 1. Experiment 1 was conducted with seventy-one high school students where participants were presented with instructional materials to assist them to solve algebra problems;
- Chapter five presents the methodology, data analysis, results and discussion for Experiment 2. Experiment 2 was conducted with two hundred and fifty-two tertiary education students where participants were presented with instructional materials to assist them to solve algebra problems. These problems were different than those presented in Experiment 1;
- Chapter six reports methodology, data analysis, results and discussion for experiment 3, a further investigation with ninety-two high school students. These problems were different to those presented in Experiments 1 and 2, and the instructional materials were presented differently;
- Chapter seven discusses the key findings from these three experiments, outlines the limitations of the study, and concludes by providing suggestions for future research and explaining the implications this study has for advancing cognitive
load theory as well as providing some advice on how the findings from this study could be applied in practice.
This literature review critiques two major areas of research relevant to the research questions posed in this study: Cognitive Load Theory (CLT) research that focuses on the limitations of working memory, and research investigating anxiety and its impact on working memory function and capacity. This literature review forms the basis of identifying a gap in this research regarding the link between instructional materials designed according to CLT and mathematics anxiety. It is this relationship that will be examined in this study.

### 2.1 COGNITIVE LOAD THEORY AND INSTRUCTIONAL DESIGN

#### 2.1.1 Human Cognitive Architecture

Working memory (WM) actively holds, manipulates and processes information; it is the memory store critical for conscious processing relevant to learning (Sweller, 1999). WM has a limited capacity; learners are limited to processing 7+/−2 pieces or chunks of information simultaneously (Miller, 1956). However, subsequent research has suggested this figure could in fact be as low as 4 pieces or chunks (Cowan, 2001). Nevertheless, these findings suggest that WM is extremely limited. What constitutes a piece or chunk of information is dependent on a learner’s prior knowledge held in long-term memory (LTM). It is prior knowledge held in LTM that enables the chunking of information in WM. Chunking is made possible by the learner establishing patterns in information to be processed or attaching meaning to the information according to their prior knowledge, so that individual pieces of information can be grouped together; a list of numbers may be remembered if they are converted into dates or times, letters may be grouped together to form acronyms. For example, IPMAT may be used to remember the names of the phases of mitosis in cell division: interphase, prophase, metaphase, anaphase, and telophase. As information related to a particular domain increases in long-term memory, correspondingly so too does the size and sophistication of the chunk in WM. It is the increase of knowledge held in LTM that leads to the development of expertise. Further to the previous example, expertise would enable a learner to use the acronym IPMAT to not only retrieve the names of the phases of mitosis, but also the
details of what occurs during each phase identified. There is no limit to the amount of information that can be processed, that is, the size of the chunks, only the number of chunks of information. When information to be remembered is mentally grouped together to create larger, meaningful “chunk”, the amount of information able to be processed by WM is similarly greater (Chase and Simon, 1973). As domain-specific knowledge increases for a learner, chunks become more rich and complex in their interconnectedness. These chunks improve a learner’s capacity to transfer and retrieve information within the finite capacity of WM (Ericsson & Kintsch, 1995). These chunks of domain specific knowledge are organised into cognitive constructs known as schemas in long term memory. The availability of these schema and the level of automaticity increases as a learner acquires expertise within a particular domain (Sweller et al., 1998). This makes it possible for a learner to perform a task without conscious effort, and the associated load on WM is therefore reduced.

Working memory was initially treated as a unitary structure, a short-term store with connections to both sensory memory and long-term memory (Atkinson & Shiffrin, 1968). However current models assume that WM consists of multiple processors (Baddeley, 2000, 2007). These multiple processors are frequently associated with the separate processing of visual-spatial and language-based material. For example, Baddeley and Hitch’s (1974) three-component model of WM consists of a control system of limited attentional capacity, referred to as the central executive and two subsidiary storage systems: the phonological loop, responsible for sound and language, and the visuospatial sketchpad, responsible for two and three-dimensional objects. In general, the phonological loop deals with auditory material while the visuospatial sketchpad deals with visual material (see Figure 2.1).
Research by Baddeley and Hitch (1974) has provided evidence suggesting the relative independence of the visuospatial sketchpad and the phonological loop. It has been argued that the two stores process different types of information. Therefore, when information can be represented in two different ways, an image and text, both encoding and retrieval are enhanced as the information is processed in two independently operating WM sub-systems. This is referred to as dual-coding theory (Paivio, 1986). Consequently, the way in which information is presented (i.e., visual or auditory) may determine the total amount of information that can be processed in WM. Therefore theoretically, it is possible to increase effective WM capacity by presenting information in a mixed visual and auditory mode rather than a single mode.

Penney (1989) provided two lines of evidence demonstrating an increase in effective WM capacity with the use of both visual and auditory processors, rather than a single processor. Firstly, an improved ability in performing two concurrent tasks when information was presented in a partly auditory, partly visual format, rather than in either single format, and secondly, improved memory when information was presented to two
sensory modalities (visual and auditory) rather than one. Of importance is the notion that the capacity of working memory can be effectively either enhanced or compromised by the presentation of information.

This section has provided an overview of working memory and its place within human cognitive architecture. Working memory plays an integral role in cognitive processing. The limitations associated with working memory provided the impetus for cognitive load theorists to investigate effective instructional design that considers human cognitive architecture.

2.1.2 Cognitive Load Theory and Working Memory

Cognitive load can be defined as the effort associated with cognitive processing required to undertake a learning task. As discussed in Section 2.1.1, the load able to be managed by WM is finite due to the limited capacity of WM. Cognitive load theory (CLT) focuses on the limitations associated with WM capacity and the resulting processing ability of a learner during instruction (Paas, Renkl & Sweller, 2004). As such, recommendations regarding the design of instruction are proposed to support the learner to process information more efficiently within the limitations of WM capacity.

CLT is concerned mainly with biologically secondary knowledge (Paas & Sweller, 2012; Wong, Marcus, Ayres, Smith, Cooper, Paas & Sweller, 2009). Biologically secondary knowledge, although it is considered culturally important, individuals have not evolved to acquire such knowledge (Sweller, 2015; Tricot & Sweller, 2014). This knowledge cannot be learned easily, requiring cognitive effort and consciousness, and needs to be explicitly taught (Geary, 2007). Therefore, the limitations associated with WM are relevant to the learning of biologically secondary knowledge only. Examples of biologically secondary knowledge include domain specific and culturally relevant knowledge that is taught throughout the education of an individual, such as mathematics. Conversely, biologically primary knowledge refers to important and complex knowledge for which one has evolved predetermined dispositions to acquire without conscious awareness or explicit instruction (Paas & Sweller, 2012). These are generally not taught in educational institutions and include speaking a first language and
basic social interaction. Instructional design according to the principles of cognitive load theory is a key consideration to facilitate the successful acquisition of biologically secondary knowledge in areas of learning such as mathematics.

### 2.1.3 Cognitive Load Theory and Learning

Research suggests that a reduction in extraneous cognitive load does not automatically result in an increase in the germane load applied to a task (Ciernak, Scheiter & Gerjets, 2009; Chen & Hsieh, 2011; van Merriënboer, Schuurman, de Croock & Paas, 2002). Students make a decision regarding the investment of cognitive resources in learning. Having these resources available does not automatically lead to their application in the learning task. Therefore, germane cognitive load is dependent on the learning orientations of the individual, on affective and motivational aspects of learning (Schnotz & Kurschner, 2007). Kalyuga (2011) identified that the best instructional design results in a reduction in extraneous load allowing maximum WM resources potentially available for learning. With sufficient germane resources available for learning, whether they are devoted to the task, or not, may be dependent on the engagement, attitude and motivational disposition of the learner as well as student emotions such as anxiety (van Merriënboer & Sweller, 2005). It is the actual amount of working memory resources that are allocated to a learning activity that determines learning effectiveness and efficiency. Learners are engaged in a task if they invest sufficient germane resources to learning. Kalyuga (2011) considers this a critical issue in teaching and learning, which has not been explained within the framework of CLT. The research proposes that CLT sufficiently explains the load associated with a learning task. However, the specific techniques required for the allocation of germane resources to the task, although critical, lies beyond the current scope of CLT. There is a need to investigate such specific methods and techniques that consider factors such as affective aspects associated with learning.

While CLT compliant instructions aim to reduce extraneous load, CLT also aims to reduce intrinsic load when insufficient WM is available in order to successfully manage a learning task. Intrinsic load can be minimised under such circumstances by simplifying procedures or concepts, modifying schemas, pre-training or encouraging
rote learning within the initial stages of learning (Pollock et al., 2002; van Merriënboer, Kirschner, & Kester, 2003). However, learning is a complex process that may not easily be explained by a simple one to one correspondence between one cognitive load type and one instructional design component (Cierniak et al., 2009). Schnottz & Kurschner (2007) assert the need to know more precisely why specific instructional manipulations are effective under specific conditions. CLT research has therefore provided considerable evidence and guiding principles for effective instructional design in view of the limited capacity of WM. However, research conducted to date has not taken into account the impact of anxiety on the cognitive load associated with a task, nor the cognitive load effects identified. Investigations into how this may be incorporated into learning strategies, bearing in mind not only a learner’s level of expertise, but also affective and motivational aspects of the learner, is required.

2.1.4 Types of Cognitive Load

Cognitive load theory has identified three types of cognitive load that require WM resources. These elements have been referred to as ““good” (germane), “bad” (extraneous), or just there (intrinsic)”” (de Jong, 2010, p. 125). The following section explains each of these types of load in more detail.

2.1.4.1 Extraneous Cognitive Load

Extraneous cognitive load is determined by the manner in which information is presented to learners (task design) and the learning activities required of them (task selection). As a result of extensive research, educators have become aware of the most effective ways to manipulate instructions to reduce extraneous cognitive load (Paas, Renkl, & Sweller, 2003a; Paas et al., 2004; Sweller, 1988). Recent research also indicates the physical environment may also be an important factor to consider in the level of extraneous load associated with a task (Choi, van Merriënboer, Paas, 2014).
2.1.4.2 Intrinsic Cognitive Load

Intrinsic cognitive load is determined by the degree of interactivity between elements. This load increases as the task to be learnt becomes more complex. Element interactivity determines how complex a task is for a learner and is dependent on a learner’s prior knowledge and level of expertise in a particular domain. This load is essential for learning but is unable to be altered by instructional design (Paas, et al., 2003b). However, intrinsic cognitive load may be managed by adjustments in the level of interactivity of the elements in the material presented, for example, by simplifying or segmenting a task (Atkinson, Derry, Renkl & Wortham, 2000). This scaffolding assists learning, but the material is not fully understood until the individual elements are able to be managed simultaneously by the learner (Sweller, 1994; 2010).

The level of element interactivity of a task varies according to a learner’s level of expertise and is effectively reduced as expertise increases. That is, what is considered complex for a novice may in fact be a simple task for an expert. Development of domain-specific expertise allows a degree of automaticity to be achieved, as well as schema development in long-term memory, both enabling the intrinsic cognitive load associated with a learning task to be effectively reduced. An expert’s use of perceptual cues and superior pattern recognition mechanisms are the result of enhanced chunking of domain specific knowledge, which improves performance and learning efficiency (Gobet, 2005). The greater store of domain specific prior knowledge in long-term memory and automaticity that accompanies expertise results in a reduced working memory load. The difference in the performance of experts and novices may therefore be attributed to the level of element interactivity and the automaticity of a task, which in turn, determines the intrinsic load experienced by the learner (Mayer, 1997). Furthermore, it has been suggested that aligning the difficulty of a task with a learner’s expertise is equivalent to adapting the instructional information to the learner’s zone of proximal development (Schnotz & Kurschner, 2007). Cognitive load effects, primarily for biologically secondary knowledge, have been found only to be present in conditions of high element interactivity (Sweller et al., 1998; Pollock et al., 2002). CLT suggests that an “easy” task results in a perfect performance. However, this does not take into account how anxiety and instructional design may impact performance. Tasks that are
too easy, beyond the learner’s expertise or poorly designed (that is, not designed according to the principles of cognitive load theory) may have an effect on a learner’s performance and the anxiety related to a task.

2.1.4.3 Germane Cognitive Load

Germane cognitive load is determined by the engagement of cognitive resources to support learning. It refers to the level of mental processing dedicated to the formation and automation of a learner’s cognitive schemas during the learning process (Sweller et al., 1998). This involves the student using techniques such as self-explanation, rehearsal or imagination. This may be dependent on a student’s level of metacognitive skills as well as their levels of motivation.

The three types of cognitive load identified are viewed as being additive, so it is advantageous to reduce extraneous load and manage intrinsic load so germane load can be maximised. If the total cognitive load exceeds WM capacity, learning may be inhibited. Those factors that have a beneficial impact on WM capacity, such as expertise and associated automaticity, motivation and appropriate instruction design, should be encouraged. In contrast, factors known to negatively impact the capacity of WM, such as poor instructional design and anxiety, need to be addressed and minimised (Ashcraft & Kirk, 2001).
**Figure 2.2.** An example of how varying conditions of instructional design / format and task difficulty for anxious students can impact total working memory capacity.

Figure 2.2 is a representation of the limited WM capacity as a sum of the components contributing to total cognitive load experienced by a highly anxious learner in the conditions investigated in this study. Highly anxious learners completed tasks of both low element interactivity and high element interactivity, using materials designed according to the principles of cognitive load theory (CLT compliant) or not designed according to the principles of cognitive load theory (CLT non-compliant).

Columns 1 and 2 indicate that non-CLT compliant instruction places a high extraneous cognitive load on the learner. Column 1 shows this is not detrimental for anxious individuals when element interactivity is low as this imposes a low intrinsic load. However, as shown in Column 2, when element interactivity is high, the intrinsic load experienced is much greater, potentially leaving little WM available to be allocated to germane load with a possible detrimental effect on learning. Columns 3 and 4 suggest when the design of learning materials is CLT compliant, that is load on WM is reduced, both extraneous load and anxiety experienced by the learner as a result may be
comparatively reduced. Column 3 indicates the low intrinsic load associated with low element interactivity ensures that the germane load available may be adequate for successful completion of the task. Column 4 shows when intrinsic load is increased with more complex task of higher element interactivity, sufficient WM resources are still available to be allocated to germane load and successful completion of the learning task. A summary of this is illustrated in Figure 2.2. This research aims to demonstrate the importance of instructional materials designed according to the principles of cognitive load theory for highly anxious learners. The proposed hypotheses recognise the limitations of working memory in terms of cognitive load, particularly for anxious learners. As such, the hypotheses suggest that instructional materials designed according to the principles of cognitive load theory may alleviate the cognitive load associated with mathematics tasks and therefore enhance performance for anxious learners.

Of importance is the contention in recent CLT literature regarding the definition and measurement of germane cognitive load. This research questions whether germane cognitive load is distinguishable from extraneous cognitive load and intrinsic cognitive load (de Jong, 2010; Kalyuga, 2011; Leppink et al., 2014), as well as whether germane cognitive load is actually a component of intrinsic cognitive load (Kalyuga, 2011; Leppink & van den Heuvel, 2015).

### 2.1.5 Cognitive Load Effects

There are a number of cognitive load effects that have been shown to reduce the load on working memory, that is reduce extraneous load, and support learning. The following sections provide a summary and discussion of key research in a number of these cognitive load effects relevant to the current study, namely the worked example effect, the element interactivity effect, the expertise reversal effect and the split attention effect.

#### 2.1.5.1 The Worked Example Effect

The CLT compliant mathematics instructional materials used in this research include the provision of worked examples for participants. Of all effects devised by way of
cognitive load theory research, "the worked example effect is the best known and most widely studied" (Sweller, 2006, p. 165). In order to be effective, worked examples must “reduce cognitive load (and) appropriately direct attention” with necessary information integrated into a distinct unit (Ward & Sweller, 1990, p. 36). Worked examples provide step-by-step guidance for a particular problem type that explains how to proceed from the problem state to the goal state. The cognitive load associated with this approach is very low, as students are required to focus on only one step at a time (Paas et al., 2003b). Worked examples draw learners’ attention to the problem stated and solution steps required (Algarni, Birrell, & Porter, 2012). As understanding increases partially completed worked examples can then be introduced for students to finish (Paas et al., 2003b; Renkl & Atkinson, 2003). Students are then able to practice solving similar problems to ensure they have correctly understood the procedure. Research has demonstrated these techniques enhance the learning of mathematics (Cooper & Sweller, 1987; Paas & van Merriënboer, 1994), in addition to reducing the time taken to solve problems (Sweller & Cooper, 1985). This occurs as a result of reducing extraneous load associated with problem solving by the provision of scaffolding and reducing intrinsic cognitive load during the process of schema acquisition (Paas et al., 2003b).

Worked examples are considered a more effective learning technique than actually solving the problem itself when a learner’s prior knowledge is minimal (Jelsma & van Merriënboer, 1990). The effectiveness of worked examples is dependent on the design of the worked examples, such as the particular solution used, as well as the characteristics of the learner (Moreno, 2006). Recent research indicates the need to adjust this technique according to the level of expertise, or prior knowledge, of the learner. Novices benefit from the use of worked examples due to the provision of expert guidelines for complex problems (van Merriënboer, 1997). The provision of worked examples for novices eliminates the necessity for them to adopt ineffective problem solving strategies (van Gog, Paas, & van Merriënboer, 2006). However, the need for this guidance gradually fades as learners acquire domain specific knowledge and move toward expertise where conventional problem solving does not impose such a high cognitive load (Clark et al., 2006; Renkl & Atkinson, 2003). Furthermore, worked examples may not be effective in all learning situations, for instance, when, the primary goal associated with a task is not schema acquisition. In such a case, identification of
explicit sub-goals appropriate to the phase of instruction should determine the most beneficial learning activities to be adopted (Kalyuga & Singh, 2016).

Worked examples can vary in their structure and design. The provision of product-oriented worked examples encourages students to self-explain the procedure (Kalyuga et al., 2001). Process-oriented worked examples provide feedback throughout the process in addition to encouraging self-explanation (Atkinson, Renkl, & Merrill, 2003). By encouraging a learner to adopt such elaboration procedures, worked examples increase the germane cognitive load associated with a problem-solving task, thereby enhancing learning (Paas et al., 2003b; Paas & van Gog, 2006). Brooks (2009) found the provision of both product-oriented and process-oriented worked examples provided support to learners and improved performance scores compared with learners using conventional problem solving.

Specifically for mathematics, the design of the worked example may also influence the cognitive load imposed on a learner during completion of algebra problems. The balance method, where the same operation is performed to both sides of the equation, is favoured in western research and practice, whereas the inverse method, where the opposite operation is applied to the “other” side of the equation, is promoted in Asian countries (Ngu, Chung, & Yeung, 2015). Research by Ngu et al. (2015) found the balance method to impose a greater cognitive load compared to the inverse method as a result of the interaction of more elements, that is, operations on both sides of the equation rather than only one. Despite this, the worked examples in this research have been designed according to the balance method as this is the method participants are most likely to be familiar with.

In summary, CLT research has determined the effectiveness of worked examples as a technique to provide guidance to learners and minimise the cognitive load associated with a task. Worked examples have been shown to be of particular assistance for novice learners. The usefulness of worked examples for highly anxious learners, and the most effective design of such worked examples, has not previously been investigated.
2.1.5.2 The Element Interactivity Effect

The central premise of cognitive load theory is the limitations associated with working memory. Cognitive Load Effects, such as the worked example effect have been found to be evident for tasks of high element interactivity compared to tasks of low element interactivity (Leahy & Sweller, 2005). The cognitive load on working memory is greater for tasks of high element interactivity than for tasks of low element interactivity (see Figure 2.2). This is a result of the greater intrinsic cognitive load imposed on working memory when solving complex problems (Sweller, 2010; Sweller & Chandler, 1994). Due to the additive nature of cognitive load, optimal instructional design is critical for tasks of high element interactivity. Research suggests learning support is not needed for tasks of low element interactivity (Chen, Kalyuga, & Sweller, 2015; Pollock et al., 2002). The instructional materials in this research include tasks of varying level of element interactivity in order to investigate findings for tasks of low and high element interactivity for highly anxious learners.

2.1.5.3 The Expertise Reversal Effect

Students with higher prior knowledge require less guidance in their instruction. Research has shown that the prior knowledge acquired by experts’ results in some CLT instructional techniques that facilitate learning for novices being ineffective, and even detrimental, for competent learners (Kalyuga, 2007). For students already competent in a particular domain, for example, algebra, the provision of worked examples may add to the level of cognitive load. For experts, worked examples may add a level of extraneous load as cognitive resources may be allocated to instructional materials not required by the learner to perform the task successfully. The expertise reversal effect suggests the use of worked examples may be beneficial only in the early stages of learning and less effective, potentially detrimental, at later stages of learning. Due to the influence of expertise on the cognitive load effects, this research will consider the expertise of participants, and in some cases, provide comparisons between findings for novices and experts.
2.1.5.4 The Split Attention Effect

Instructional materials containing both images and text often demand the learner to use extensive search and match processes in order to integrate the two pieces of content in order understand the information (Chandler & Sweller, 1991). This search and match process requires WM resources that are then unavailable for the learning process. Integrating multiple sources of information required for understanding into a single source, while at the same time avoiding unnecessary duplication of information (see redundancy effect in Section 2.1.5.5), reduces the cognitive load. This enhances learning by removing the need for the learner to integrate or search for required content (Chandler & Sweller, 1991, 1992).

The split attention effect arose from findings associated with the worked example effect. Worked examples with evident split attention effects were shown to be ineffective due to split source of information presented. Instructional materials with an integrated design of effective worked examples and problems to solve remove the need for learners to rely on search and match processes (Chandler & Sweller, 1992). As such, worked examples are best presented as example-problem pairs. The CLT compliant materials used in this research have an integrated instructional design to minimise the split attention effect. Conversely, worked examples provided in the CLT non-compliant condition (Experiments 1 and 2 only) were not integrated with the problems to solve. Therefore, the design of the instructional materials in this condition created a split attention effect.

Cognitive Load research has identified a number of techniques that can be utilized which successfully reduce the cognitive load associated with a learning task. The instructional materials should be designed in such a way that extraneous load is minimized and activities that support learning are encouraged (Sweller, 2010).

2.1.5.5 The Redundancy Effect

It is essential that information provided in instructional materials is not replicated. When the same information is presented in a variety of formats, the repeated
information becomes redundant and WM resources allocated to processing that information impedes learning. For example, attending to both text and images that provide the same information but are able to be understood independently of each other, increases the cognitive load associated with a task without enhancing the learning process (Chandler & Sweller, 1991).

2.1.6 Measurement of Cognitive Load

Schnitz and Kurschner (2007) identify three methods used to measure cognitive load. Firstly, physiological measures which include galvanic skin responses, pupillary dilation and heart rate variability. However, the ecological validity of these techniques is low as they are unable to be used in natural learning environments. Secondly, performance based measures, such as dual task methodology, require participants to perform a primary task while simultaneously performing a secondary task, such as a simple reaction task. Finally, subjective ratings require learners to self-report the mental effort invested in a task, or the level of difficulty of a task. Several subjective rating scales have been used in CLT research, most utilising a 5, 7 or 9 point Likert Scale. Subjective measures have been found to be simple, easy to obtain, non-obtrusive, easy to analyse, reliable, valid and often more sensitive to small differences in cognitive load than physiological measures (Paas & van Merriënboer, 1994; Paas, van Merriënboer & Adam, 1994, Sweller, van Merriënboer & Paas, 1998). Research by Paas et al. (2003b) identified 24 studies between 1992 and 2002 that had successfully used this tool to “determine the power of different instructional conditions” (p. 67). For instance, Paas and van Merriënboer (1993) used participants’ subjective ratings of mental effort in combination with participants’ performance scores to effectively measure the instructional efficiency of design conditions. Likewise, Kalyuga et al. (2001) used participants’ mental effort ratings of worked examples to indicate the cognitive load associated with problem solving for novices and experts. Findings showed that the mental effort imposed by worked examples or problem solving was dependent on levels of learner expertise.

Subjective measures can be used repeatedly throughout a learning task and measure load applied to particular aspects of a learning situation. Therefore, one is able to
assume a direct relation between subjective measures and the actual cognitive load associated with specific aspects of the learning task. Learners are able to reflect on their personal cognitive processes and apply numerical values to mental effort and mental load experienced during a learning task (Paas et al., 2003b). In addition, by keeping extraneous load and germane load constant, Ayres (2006a) argues the ability to identify specific changes in intrinsic cognitive load for tasks of varying element interactivity. Findings suggest that subjective measures were “highly reliable, varied significantly within problems and correlated highly with errors” (Ayres, 2006a, p. 389).

This study will use the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992), adapted from Bratfisch, Borg and Dornic (1971). Participants rank their experienced level of cognitive load (Paas, 1992) and perceived task difficulty (Kalyuga, Chandler & Sweller, 1999) on a 9-point likert rating scales ranging from extremely low (1) to extremely high (9). This one-item measure has been used extensively in CLT research (Ayres, 2006b; Chen & Chang, 2008; Li & Liu, 2007; Paas, 1992; Paas & van Merriënboer, 1994; Paas, van Merriënboer & Adam, 1994; van Merriënboer et al., 2002). Measures of mental effort such as this can be used to measure learning efficiency according to the following equation: \( E = \frac{1}{\sqrt{2}} \left( M - \frac{p}{l} \right) \) (Paas & van Merriënboer, 1993). However, this one item mental effort measure does not differentiate between the types of cognitive load, and as such, it is unclear as to what type of cognitive load it is actually measuring (Leppink, 2017).

Despite the need for an instrument able to distinguish between extraneous, intrinsic and germane cognitive load, attempts to identify different loads for a specific learning task simultaneously by slight variations in questions have been less successful (Cierniak, Scheiter & Gerjets, 2009; Paas et al., 2003b). However, an instrument recently developed, consisting of 10 items, has been found to be effective for the measurement of the three types of cognitive load (ICL, ECL and GCL) (Leppink et al, 2013). This scale has been used across a number of domains, with some variation to address the evolving narrative concerning germane cognitive load. Leppink, Paas, van Gog, van der Vleuten and van Merriënboer (2014) tested this measure using pairs of worked examples and problems. Findings indicated that this instrument effectively
discriminated between extraneous cognitive load and intrinsic cognitive load. Further research in the design of medical education utilised a two-factor version of the instrument to successfully differentiate between extraneous and intrinsic cognitive load only (Leppink & van den Heuvel, 2015). Likewise, a study by Bergman, de Bruin, Vorstenbosch, Kooloos, Puts, Leppink, Scherbier, and van der Vleuten (2015) utilised this instrument in the domain of medical education. However, all items of the instrument were used, reclassifying items related to germane cognitive load as “self-perceived learning”. These items successfully predicted performance scores. In circumstances where it becomes necessary to distinguish between types of load, this instrument provides high reliability and validity. This measure will be used in this study but is not able to be used to calculate learning efficiency.

Considerable controversy exists concerning the definition and measurement of germane cognitive load. Recent research has led to what has been referred to as a “reconceptualization” of CLT (Kalyuga, 2011). Firstly, research questions the extent to which germane cognitive load is able to be distinguished from both extraneous cognitive load and intrinsic cognitive load (de Jong, 2010; Kalyuga, 2011; Leppink et al., 2014). This is particularly evident when considering a learner’s level of expertise. Furthermore, the research posits the consideration of germane load as a component of intrinsic load (Kalyuga, 2011; Leppink & van den Heuvel, 2015). Difficulty differentiating between the two types of load empirically (Paas & van Merriënboer, 1994) and with both ultimately contributing to the achievement of learning goals supports this suggestion. Secondly, the measurement of germane cognitive load using Items 7-10 of the scale developed by Leppink et al. (2013) relies on a learner’s understanding of a task as a subjective measure of germane cognitive load. This does not align with the accepted definition of germane cognitive load (Ayres, in press). Leppink et al. (2014) later referred to this as germane resources. Subsequent research has referred to the findings from these four items as “self-perceived learning” which more accurately describes the construct depicted (Bergman et al., 2015; Hadie & Yusoff, 2016). However, for the purposes of this research, this measure will be referred to as germane cognitive load, indicative of the investment of germane resources, in keeping with the scale as devised by Leppink et al. (2013). This scale has been identified as a useful construct to differentiate between different types of cognitive load.
However, any interpretation of results pertaining to germane cognitive load may be interpreted as “self-perceived learning” (Bergman et al., 2015) or “understanding” (Ayres, in press) consistent with currently evolving research.

Recent research has advocated and adopted the use of more than one scale for the measurement of cognitive load in order to generate more comprehensive and consistent findings in terms of both the level and type of cognitive load experienced during a learning task (de Jong, 2010; Krell, 2015; Naismith, Cheung, Ringsted, Cavalcanti, 2015). This research will use the Cognitive Load Subjective Rating Scale (Paas, 1992) to measure mental effort and will also use the 10-item instrument developed by Leppink et al. (2013) to measure ECL, ICL and GCL.

2.1.7 Summary of Cognitive Load Effects

The limitations associated with working memory have directed cognitive load theory research. The finite capacity of working memory necessitates favourable instructional design to support the learner with cognitive processing. The cognitive load associated with mathematics tasks may be minimised with effective instructional design, such as the use of worked examples. Worked examples reduce the extraneous cognitive load associated with a task, particularly when the task is high in element interactivity, that is, has a high intrinsic cognitive load. This research will investigate cognitive load for highly anxious learners by measurement of the extraneous, intrinsic and germane cognitive load for simple and complex algebra tasks.

2.2 ANXIETY

2.2.1 Introduction

Anxiety refers to an emotional response often involving fear and uncertainty, and is generally disproportional to the threat concerned (Sarason, 1984). Anxiety is thought to be composed of three factors: psychological (cognitive apprehension), physiological (arousal including increased heart rate, muscle tension and sweat gland activity) and behavioural (nervousness, aversion and poor performance) (Borkovec et al., 1977).
Anxiety may be considered trait anxiety, a predisposition, or proneness to anxiety or state anxiety, a specific situational, emotional reaction (Spielberger, 1972). The effects of anxiety vary from task to task and interact with task difficulty. The detrimental effects of anxiety increase as task difficulty, or complexity, increases (Eysenck, 1985). The Yerkes-Dodson Law (as cited in Eysenck, 1985) provides an explanation of the curvilinear relationship between arousal and performance and states that performance increases with some degree of arousal, but only up to a point. Beyond this point, performance is reduced and the effects can be detrimental. This optimum level of arousal is reduced for difficult or complex tasks to facilitate information processing and minimise “waste” of WM resources. That is, the optimum level of arousal varies inversely with task difficulty (Eysenck, 1985). Figure 2.3 shows the relationship between the level of anxiety (or arousal) and performance for tasks of varying levels of difficulty. The adverse effect of anxiety on performance is greater during completion of more complex tasks (Eysenck, 1985).

**Figure 2.3.** The Yerkes-Dodson Law 1908. From “Yerkes-Dodson Law”, by The Daily Omnivore, 2013, (https://thedailyomnivore.net/2013/04/17/yerkes-dodson-law/). In the public domain.
Anxiety may consume WM and therefore competes with learning and impacts performance. Individuals experiencing high levels of anxiety incur a higher cognitive load and both are negatively correlated with comprehension (Chen and Chang, 2008). Much research has been undertaken in this area concerning stage fright as a result of performance anxiety and “choking” in sport (Beilock & Carr, 2001; Oudejans & Pijpers, 2010). There is a need to further investigate the impact of emotion, namely anxiety, on education and learning of biologically secondary knowledge (Ayres & Paas, 2009; Low, Jin & Sweller, 2009). Investigation of how levels of cognitive load, anxiety and performance differ across different levels of ability and perceived task difficulty may contribute to establishing a model incorporating these variables to infer causal relationships and obtain a deeper understanding of the role of affective factors in intellectual cognitive activities (Chen & Chang, 2008). This research proposed will provide empirical evidence towards a greater understanding of the relationship between anxiety and instructional design through measurement of these factors, cognitive load, anxiety and performance, concurrently for a series of tasks of varying complexity.

### 2.2.2 Anxiety and Working Memory

Extensive research from as early as the 1970’s has indicated a relationship between WM and anxiety (Sarason, 1978; Spielberger, 1972). Studies continue to consistently show that experiencing anxiety, particularly high levels of worry, is detrimental to WM capacity (Eysenck & Calvo, 1992; Eysenck, Santos, Derakshan & Calvo, 2007). As a result, cognitive theories such as attentional control theory (Eysenck et al., 2007) and processing efficiency theory (Eysenck & Calvo, 1992) suggest that high levels of trait anxiety predict adverse effects on the performance of cognitive tasks, particularly those that make high demands on cognitive resources. More specifically, Shackman, Sarinopoulos, Maxwell, Pizzagalli, Lavric and Davidson (2006) investigated how “task-irrelevant affect modulates cognition” (p. 40). Their findings suggest that high levels of anxiety (using a self-report anxiety scale and threat-induced anxiety) disrupt visuospatial WM task performance due to competition for WM resources between task-irrelevant anxious thoughts and spatial processing. A study by Moriya & Sugiura (2012) examined the effects of WM load on visual attention. Results indicated that although
socially anxious people could potentially hold a large amount of information in working memory, ... [due to] an impaired cognitive function, they could not inhibit goal-irrelevant distractors and their performance decreased under highly demanding conditions” (Moriya & Sugiura, 2012, para. 1). Anxiety disrupts sensory, perceptual and attentional processing by favouring task-irrelevant anxious thoughts (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007) that subsequently reduces working memory capacity available for learning due to competition for working memory resources (Eysenck & Calvo, 1992). Furthermore, a study by Owens, Stevenson, Hadwin and Norgate (2008) examined whether the link between anxiety and performance was facilitated by poor performance on verbal and spatial WM tasks. Findings suggest test performance in adolescents displaying trait anxiety was dependent on WM capacity, with low WM capacity having a negative effect on test performance and a positive relationship between test performance in those with high WM capacity. A meta-analysis of neuro-imaging studies by Owen, McMillan, Laird & Bullmore (2005), confirms anxiety is likely to affect working memory. Furthermore, it suggests various components of anxiety, such as apprehension and arousal, affect working memory differently. Anxious apprehension is more likely to disrupt verbal WM whilst anxious arousal is more likely to disrupt spatial WM. More specifically, spatial working memory has been found to be impaired by anxiety regardless of the difficulty of the task completed, that is, “under both low and high cognitive load” (Vytal, Cornwell, Letkiewicz, Arkin & Grillon, 2013). Overall, working memory capacity and performance is significantly reduced in individuals with trait anxiety (Darke, 1988a; Eysenck, 1998).

Research suggests convergence in time and space may influence the impact of stress and anxiety on learning. This implies stress will only be of benefit in learning environments if it is experienced in the same context and at the same time as an event needs to be remembered. Performance is otherwise impaired as a result of anxiety experienced (Jeols, Pu, Weigert, Oitzl & Kruges, 2006). The extent of the impact of anxiety on performance is determined by individual differences in terms of allocation of WM resources prior to a complex mathematics task, as well as a learner’s motivation (Lyons & Beilock, 2011). Emotion control treatments are capable of generating more positive emotions and higher motivation; a negative correlation exists between anxiety
and motivation (Kim & Hodges, 2011). Further, efficiency, more than effectiveness, is characteristically impaired by anxiety (Hunt, 2011, p130). Research by Calvo, Ramos & Estevez (2007) suggests that for anxious learners, a deficit in prior knowledge impacts learning efficiency even more than a reduction in working memory capacity. However, the interaction between working memory and anxiety appears to be similar for both adolescents and adults (Patel, Vytal, Pavletic, Stoodley, Pine, Grillon & Ernst, 2016). It is necessary to identify how specific learner characteristics such as anxiety impacts the engagement of WM resources and therefore affects the efficiency of learning, learner performance or commitment to learning. The proposed research will investigate the benefit of CLT compliant instructional materials for anxious learners, as well as the potential to reduce anxiety in learners through the use of such materials. This may ultimately have further positive implications for learning such as greater satisfaction and motivation in the learning environment.

2.2.3 Anxiety and Mathematics

2.2.3.1 Student Anxiety

There has been extensive research about anxiety associated with the learning of mathematics, including key research by Richardson & Suinn (1972), Hembree (1990), Ma (1999), and Ashcraft & Kirk (2001). In addition to the notion that state anxiety may be perceived as multidimensional, researchers such as Martens (1977) and Sarason (1978) support the use of situation-specific assessments of anxiety (Caruso, Dzewaltowski, Gill & McElroy, 1990). Mathematics anxiety is primarily considered state anxiety and is often related to poor performance in the subject, a negative attitude towards the subject and general avoidance of the mathematics (Hembree, 1990). However, it is not clear whether anxiety leads to a poor performance in mathematics or whether poor performance creates anxiety related to the subject. As the directionality of the relationship has not yet been established, further research is required (Devine, Fawcett, Szücs & Dowker, 2012). Mathematics anxiety has been associated with physiological hyper-arousal such as increased heart rate, (Carroll, Turner & Prasad, 1986) and increased sweat gland activity (Dew, Galassi & Galassi, 1983). It is understood that the relationship is established in the early years of schooling and
impacts future decisions to pursue mathematics subjects and careers (Brown et al., 2008). For example, the percentage of Year 12 students nationally enrolled in mathematics at an advanced level has dropped from 14.1% in 1995 to 11.7% in 2004 (with only 3.2% of students in the Northern Territory) (Coupland, 2006). In 2004, 20% of Year 12 students were not enrolled in mathematics at any level (Barrington, 2006). This decline in participation rates, particularly at the higher levels of mathematics, is believed, at least in part, to be associated with mathematics anxiety. Reducing mathematics anxiety and the resultant negative impact it has on the learning of mathematics may “enable and encourage students to reach their full potential in mathematics” and be more inclined to pursue mathematical endeavours (Taylor and Fraser, 2013, p298).

Maths anxiety and the accompanying preoccupation with anxious thoughts impacts mathematics performance. This is due to the relationship between the two essentially operating as a dual-task procedure (Ashcraft & Krause, 2007). As a result, processing relevant to the mathematics task, the “primary task, is degraded because the secondary task, the anxiety reaction, compromises the capacity of working memory” (Ashcraft & Kirk, 2001, 236). Furthermore, findings by Beilock and Carr (2005) show that pressure associated with problem solving in mathematics, or “choking”, which compromises working memory capacity, is most likely to effect those “most qualified to succeed” (p. 101), that is, those with the ability to successfully complete complex mathematics tasks. As such, performance scores of learners with high math anxiety underestimate their true ability, and alleviation of this anxiety may lead to improved achievement in mathematics (Ashcraft & Moore, 2009).

A number of studies have investigated the use of interventions to alleviate the anxiety associated with mathematics. These include eye movements, verbal shadowing, copying a complex figure and complex counting tasks. These secondary tasks compete with anxiety for limited WM resources with the effect of reducing the vividness and adversity associated with anxiety during a complex learning task (Gunter & Bodner, 2008; van den Hout et al., 2010). Research by Dutke and Stober (2001) found high sequential demands could be adopted to relieve WM of maintenance processes in complex tasks for highly anxious individuals. This had a beneficial effect on both the
speed and accuracy of their performance. This was due to tasks with high sequential demands promoting the regular updating of WM contents for learners rather than requiring them to store larger amounts of information in WM. Such interventions support anxious students by reducing the load on WM as they are required to focus on one step at a time. Worked examples, such as those used in the instructional materials in this study, may provide such support.

Another approach suggests, “that individual difference variables like math anxiety deserve greater empirical attention, especially on assessments of WM capacity and functioning” (Ashcraft & Kirk, 2001, p. 224). Strategies which actually resolve deficiencies in working memory, such as computerised cognitive training, can lead to improved working memory capacity and improved maths performance (Sevey, 2012). The approach used in this research provides an alternative strategy to address the limitations of working memory which structures mathematics instruction according to the principles of CLT. This strategy may ensure that anxiety is alleviated before it is able to have a detrimental impact on learning and performance in mathematics. Effective instructional design, in terms of CLT, may assist highly anxious learners to manage the impact of anxiety on working memory and cognitive load. This would increase the capacity of the highly anxious learner to cognitively engage with the instructional materials. The theoretical findings related to cognitive load effects may facilitate a reduction of the anxiety experienced by highly anxious students in mathematics. This may then enable the identification of specific strategies that can be utilised by the student or the teacher in the learning environment to maximise the management of cognitive load and allocation of germane resources to support the understanding and successful completion of complex tasks. This research will specifically examine the use of CLT compliant materials in mathematics instruction and the potential this has to improve the performance of anxious learners and relieve anxiety associated with mathematics for these learners.

2.2.3.2 Teacher Anxiety

Mathematics teachers ultimately influence student anxiety associated with learning mathematics in the classroom (Beilock, Gunderson, Ramirez & Levine, 2010; Brown, et
Currently, students are able to enter some primary teaching courses at university without completing Year 10, 11 or 12 mathematics (Rubenstein, 2009). This infers some avoidance of mathematics for which a negative attitude may exist. In addition, teacher’s attitudes to mathematics have a strong influence on a student’s perception, enjoyment and success in mathematics (Beilock et al., 2010; Brown et al., 2008). It is therefore important to improve teachers’ attitudes to mathematics by alleviating anxiety associated with the subject. This will ensure teachers do not impose their own anxiety towards maths on to their students during instruction.

Arguably it’s true that mathematics instruction most often uses materials that have three main components: introductory explanatory instructions, worked examples to demonstrate the new mathematical concepts and a large number of problems or exercises for the learner to complete (Chandler & Sweller, 1991; Renkl & Atkinson, 2003). Extensive practice with associated feedback is crucial to learning efficiency as it enables the learner to automate certain tasks, which reduces the load on WM. In order for this instruction to be most effective, it is necessary for teachers to demonstrate expertise and a positive attitude towards mathematics. This may then have a positive impact on teaching mathematics by adopting a more favourable approach, including developing varied, relevant and novel approaches to mathematics instruction (Furner & Duffy, 2002). Mathematics instruction informed by the principles of cognitive load theory may improve teacher expertise and alleviate teacher anxiety and therefore, alleviate student anxiety and improve students’ attitudes and performance in mathematics.

2.2.4 Measurement of Anxiety

Anxiety research commonly uses subjective self-report measures for the assessment of anxiety. Although this may be interpreted as a limitation, many of these measures have been frequently validated, analysed, revised and abbreviated to ensure simple, reliable and accurate measurement of anxiety (Hopko et al., 2003a). Self-report measures from adolescents regarding social anxiety symptoms demonstrate “high levels of internal consistency and convergent validity” (De Los Reyes, Aldao, Thomas, Daruwala, Swan, Van Wie, Goepel & Lechner, 2012, p. 308). However, subjective measures correspond
poorly with objective psychophysiological measures, such as heart rate (Dew, Galassi, & Galassi, 1984; Des Los Reyes et al., 2012), skin conductance (Hopko et al., 2003b), sweat gland activity (Clements & Turpin, 1996) and cortical activity (Dew et al., 1984). Conversely, these findings suggest little or no relationship between mathematics anxiety and physiological reactivity. At best, the research on the physiological effects of maths anxiety is inconsistent (Medeiros & Leclercq, 2007). This research therefore adopts a self-report measure of anxiety.

The Revised Mathematics Anxiety Rating Scale (R-MARS) (Alexander & Martray, 1989) is a 25-item version of the original 96-item Math Anxiety Rating Scale (Richardson & Suinn, 1972) answered on a 5-point Likert Scale, from 0 (no anxiety) to 4 (high anxiety). The prevalent use of this scale in the literature on maths anxiety and analysis of psychometric data (Hopko, 2003a; Plake & Parker, 1982; Richardson & Suinn, 1972; Suinn & Winston, 2003), warrant the use of this scale in the development of future tools. The R-MARS and associated subscales were found to have moderate-to-high-reliability. Reliability is “the degree to which a measure is consistent or dependable; the degree to which it would give you the same result over and over again, assuming the underlying phenomenon is not changing” (Trochim and Donnelly, 2007, p. 315). Initial internal consistency reliability coefficients of the R-MARS subscales were excellent for Mathematics Test Anxiety ($\alpha = .96$) and good for both Numerical Task Anxiety ($\alpha = .86$), and for Math Course Anxiety ($\alpha = .84$) (Alexander & Martray, 1989).

Recent research (Baloglu & Zelhart, 2007; Hopko et al., 2003a) suggests insufficient investigation of psychometric properties of the R-MARS, particularly in terms of validity. An abbreviated math anxiety measure has been developed which posits “a more parsimonious and valid approach to assess mathematics anxiety” (Hopko et al., 2003a, p. 178). The Abbreviated Math Anxiety Scale (AMAS) is a nine-item measure, which is answered on a 5-point Likert Scale, from 1 (“not at all”), to 5 (“very much”). The instrument addresses maths anxiety in a variety of settings from performing non-assessment routine maths tasks to high-stakes testing scenarios (see Figure 2.4).

Internal consistency within the AMAS is high (α = .90), as well as for Learning Math Anxiety (LMA) subscale (α = .85) and Math Evaluation Anxiety (MEA) subscale (α = .88). Two-week test-retest reliability for the AMAS was also strong (r = .85) as well as for the subscales MEA (r = .83) and LMA (r = .78). Strong convergent and divergent validity was demonstrated (see Figure 2.5).

In addition, the use of subjective judgments, such as “indicate your current mathematics anxiety level” have been shown to be significantly positively correlated with scales such as R-MARS allowing quick assessment of mathematics anxiety levels throughout an experimental procedure (Baloglu & Zelhart, 2007). The AMAS is therefore a valid and reliable modified version of R-MARS. Baloglu and Zelhart (2007, p. 608) suggest the AMAS provides a useful tool for:

- Mathematics instructors to identify highly anxious students at-risk in their courses;
- Counselors to detect specific problem areas within mathematics anxiety and create intervention strategies;
- Researchers to study the relationships between mathematics anxiety and other factors, such as WM, cognitive load and implementation of effective instructional design for anxious students.

The AMAS will thus be used in the present study as the mechanism to determine highly anxious and low anxious learners. In addition, the level of anxiety measured may impact task satisfaction, importance and engagement of a learner.

### 2.3 COGNITIVE LOAD THEORY AND EMOTION

It is therefore evident that a relationship between maths anxiety, maths performance and working memory exists. Maths anxiety consumes limited working memory resources that, in turn, have a detrimental effect on mathematics performance for highly anxious learners. Unpleasant emotional states reduce the availability of working memory resources for processing (Gray, 2001). This study investigated the learning support provided by instructional materials designed in accordance with the principles of cognitive load theory by highly anxious learners. This section reviews how cognitive load theory may be able to contribute to this relationship and enhance maths instruction for highly anxious learners.


2.3.1 Cognitive Load Theory and “Negative” Emotion

A number of recent studies have investigated the impact of emotion on cognitive load and learning. Learners often experience some level of confusion when processing complex information. Prolonged confusion, leading to frustration and boredom during a learning task, can have a detrimental effect on the learning experience and learning outcomes. Interventions to “modify” and “resolve” confusion through instructional design allow learners to detect their personal confusion and direct their learning approach within the “zone of optimal confusion” towards greater engagement in the learning task (Arguel, Lockyer, Lipp, Lodge, & Kennedy, 2017, p. 542-544).

Much of the current research has been conducted in the area of medical education due to the complexity of the tasks and the emotion associated with the learning content. Studies by Fraser, Huffman, Ma, Sobczak, McIlwrick, & McLaughlin (2014) and Fraser, Ma, Teteris, Baxter, Wright & McLaughlin (2012) and have investigated the impact of “positive” and “negative” emotions on learning during simulation training.

Findings indicated tranquility (the opposite of agitation) was associated with reduced cognitive load. Conversely, invigoration, despite being a positive emotion, was related to increased cognitive load, due to associated task-irrelevant processing that accompanies invigoration (Fraser et al., 2012). Furthermore, exposure to negative emotional experiences resulted in increased cognitive load and poorer learning (Fraser et al., 2014). An investigation by Pawar, Jacques, Deshpande, Pusapati, & Meguerdichian (2017) into cognitive load and emotional states, specifically in complex learning scenarios with high cognitive processing demands, indicate well designed educational experiences not only “facilitate cognitive flexibility and openness to information” and enhance transfer, they also have a “positive effect on participants’ emotional state” (p. 4). Consequently, the design of these tasks according to the principles of cognitive load theory is desirable (Young, van Merriënboer, Durning, & Cate, 2014).

Physical characteristics of the learning environment, such as temperature and seating arrangements, may impact learners’ ability and desire to actively participate in learning. Poor quality learning environments have a negative impact on learning due to the
adverse affect and associated lack of cognitive resources allocated to a learning task (Choi et al., 2014). Furthermore, studies by Smith and Ayres (2014a, 2014b) investigated the impact of persistent pain on working memory resources and task performance. Findings suggest persistent pain “interrupts and consumes working memory resources” and worsens performance due to interference with information retention and transfer (Smith & Ayres, 2014a, p. 245). The learning task is compromised due to preferential processing of task irrelevant information associated with the pain. This competition for limited working memory resources brings about effects in contrast to those proposed by the modality effect and the redundancy effect. That is, for those with persistent pain, narrated text provided no performance benefit, and the provision of written text identical to narrated and illustrated instruction was not detrimental to performance, respectively (Smith & Ayres, 2014b).

2.3.2 Cognitive Load Theory and Anxiety

Research confirms there are a variety of factors that influence learning, including personality, motivation and anxiety, and these have been found to be key elements in students’ academic performance and success (Handley, 2010). The amount of WM available for learning is dependent on the total cognitive load associated with a task. Instructional materials designed in accordance with CLT reduce the level of extraneous cognitive load experienced by a learner. When learning highly complex information (e.g. mathematics) where there is high element interactivity there is a corresponding increase in intrinsic load. Under these conditions it is important that learning materials comply with CLT principles. This dynamic of reducing extraneous load when intrinsic load is high, may be of critical importance when a learner’s WM capacity is compromised, for example when the learner is anxious. Research suggests highly anxious students have a reduced WM capacity (Ashcraft & Kirk, 2001). Highly anxious learners exhibit significantly smaller measures of WM capacity compared with low anxious learners (Darke, 1988a; Eysenck, 1998). When working memory is compromised, for example by anxiety, this has a detrimental effect on mathematics performance (Gathercole & Pickering, 2000). High levels of anxiety hinder maintenance rehearsal and reduce both the storage and processing capacity of WM due to a tendency to engage in task-irrelevant processing (Darke, 1988b). Therefore, if instructional
design successfully reduces extraneous cognitive load and maximises available WM, anxious students could benefit from the additional WM resources available. Furthermore, disruptions to learning as a result of anxiety may also be evident when learners are solving simple tasks because available working memory resources more freely engage in anxious thoughts (Vytal et al., 2013). As a result, cognitive load effects, previously shown only when element interactivity is high, may be shown to be evident for tasks of low element interactivity for highly anxious learners. The reduction in cognitive load afforded by instructional materials designed according to the principles of CLT may also alleviate the anxiety experienced by anxious learners, thus allowing them to achieve to their full potential.

2.4 CONCLUSION

Cognitive load theory encompasses consideration of working memory, learner performance, cognitive load and element interactivity in the design of effective instructional materials. Cognitive load theory has informed effective instructional design based on the limitations of working memory. This has been done by reducing extraneous cognitive load and maximising germane cognitive load, specifically for tasks that incur a high intrinsic load. Anxiety consumes working memory resources, and anxiety is particularly prevalent in the domain of mathematics. Consequently, instructional materials that provide working memory support are of particular importance to highly anxious learners.

This research aims to provide additional evidence for the negative relationship that exists between maths anxiety and maths performance, as well as the negative relationship between maths anxiety and the load on working memory. For anxious maths learners, in order to improve performance and reduce mathematics anxiety, it is necessary to address the deleterious effect that anxiety has on working memory. Instructional design according to the principles of cognitive load theory may provide the means with which to address this impediment for maths anxious learners. The relationship between CLT and anxiety has previously not been directly investigated and thus is the focus of this study.
This study examines the interrelationship between working memory, cognitive load and anxiety through the use of instructional materials designed according to principles of cognitive load theory. This study investigates the use of CLT compliant instructional materials in the domain of mathematics for participants identified as low or high maths anxious. The following chapter will provide an overview of the methodology for the three experiments comprising the current research.
3 RESEARCH METHODOLOGY

3.1 INTRODUCTION TO EXPERIMENTS

The theoretical framework that underpins this research study is that WM capacity is limited and WM resources need to be optimally allocated in order for learning to occur. CLT has provided insight into the effective design of instructional materials in order to reduce the extraneous cognitive load of a complex task. CLT principles associated with instructional design make efficient use of WM, which is of particular importance when WM resources are consumed with task-irrelevant thoughts, common in anxious students. This has a positive impact on learning by improving the performance of the learner, particularly for complex tasks with high element interactivity and a correspondingly high intrinsic cognitive load. CLT proposes that if the load associated with a particular cognitive task is greater than WM resources available, learning will be negatively impacted. Anxiety and poor performance are two key factors influencing participation rates and retention rates in mathematics (Hembree, 1990). This research study examined the relationship between CLT and anxiety, something not previously investigated. This chapter provides an overview of the research methodology applied in the experiments that comprise this thesis.

3.2 RESEARCH DESIGN

3.2.1 Between Subjects Experimental Design

The aim of these experiments was to examine whether instructional materials designed according to CLT are beneficial for highly anxious learners. When students fail to assign cognitive resources to a task, either because of the load associated with a task, anxiety levels or poor allocation of germane resources to a task, performance is affected. The learning task in terms of time and pressure, task difficulty and poor instructional design may contribute to anxiety levels experienced by an already highly anxious individual. Likewise, the use of instructional materials designed according to the principles of CLT may provide some relief for the learner in terms of reducing the anxiety experienced whilst completing a task, as well as improving performance as a
result of the lower extraneous cognitive load associated with the instructional materials. Furthermore, cognitive load effects, such as the worked example effect, have previously been shown to be present only when element interactivity is high. Because highly anxious individuals have a reduced working memory, some of these effects may be evident when element interactivity is low for highly anxious individuals.

Controlled experiments testing specific hypotheses, with participants randomly allocated to experimental groups, has been commonly adopted in CLT research to investigate effects associated with instructional design (Roodenrys, 2012). This research study was comprised of a series of 3 experiments. All three experiments used a between subjects design to examine the performance, cognitive load and task related anxiety of participants in a series of mathematics algebra problems of varying levels of element interactivity. Instructional materials were either CLT compliant (using process-oriented worked examples) or CLT non-compliant (using product-oriented worked examples with evident split attention or conventional problems).

The design of the worked examples provided was based on conditions suggested by Renkl (2005) in order to ensure learners’ understanding was enhanced with their use. Required features of worked examples include integrated solution steps, with each sub-goal isolated, features highlighted and instructions explained. This ensures the learner can apply the correct solution procedure when solving novel problems.

Participants in Experiments 1 and 3 were secondary school students enrolled in Stage 5 and 4 mathematics respectively. Participants in Experiment 2 were tertiary education students studying mathematics education. In all 3 experiments, participants were randomly allocated to either a CLT compliant or a CLT non-compliant instructional design conditions. Baseline maths anxiety of participants was determined using the Abbreviated Maths Anxiety Scale. Instructional conditions and baseline maths anxiety were used to create four experimental groups for analysis. Each participant completed maths algebra problems of varying levels of element interactivity. In experiment 1 and 2, participants completed 5 questions each of low, moderate and high element interactivity; in experiment 3, participants completed 10 questions each of low and high element interactivity. Even though the research questions predominantly focused on
tasks of high element interactivity, tasks of low and high element interactivity were incorporated into the experimental materials in order to validate materials, as well as allow comparison of effects at low element interactivity and high element interactivity, provide support for findings for tasks of high element interactivity and investigate CLT effects for tasks of low element interactivity (Experiment 3 only).

A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial experimental design was implemented in Experiments 1 and 2. A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2 (Element Interactivity Condition) factorial experimental design was implemented in Experiment 3. Expertise was introduced as an additional independent variable in Experiment 1 and 2. Expertise was determined using ability groupings provided by schools (Experiment 1) or by the highest level of maths successfully completed reported by participants (Experiment 2). The level of expertise of a learner in mathematics was considered to be indicative of their prior knowledge. Qualitative research methods were used to investigate findings in all three experiments. Further details are provided in Section 3.2. A pilot study was conducted prior to the commencement of Experiment 1. Two academic staff completed a full set of experimental materials for each instructional design condition. This was done to refine the materials in terms of content and expression prior to the experiment.

3.2.2 Data Collection

Table 3.1 provides a summary of the data collected in each of the three experiments, as well as the instruments used to collect the data.

Table 3.1

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety (baseline)</td>
<td>Abbreviated Mathematics Anxiety Scale (AMAS)</td>
</tr>
<tr>
<td></td>
<td>Hopko et al., 2003a</td>
</tr>
</tbody>
</table>
Dependent Variable | Instrument
--- | ---
Performance | Scores on maths tasks of low, moderate (Experiment 1 and 2 only) and high element interactivity using instructional materials designed as CLT compliant (paired process-oriented worked examples) or CLT non-compliant (separate product-oriented worked examples with split attention effects / conventional problems).
Different Types of Cognitive Load (ECL, ICL, GCL) | Leppink et al., 2013
Cronbachs α: 0.81 (ECL), 0.75 (ICL), 0.82 (GCL)
Perceived Task Anxiety | Subjective measure to “Indicate your current mathematics anxiety level” by entering any number between 0 (no math anxiety at all) and 100 (the severest math anxiety possible)” Baloglu and Zelhart, 2007, p. 597. Scale modified based on structure of CLSRS (scale from 1 to 9) for consistency.
Task satisfaction, task importance, task difficulty and task engagement | Non-validated tool based on structure of CLSRS
Efficiency | Mental effort and performance scores used to calculate instructional efficiency according to the equation:

\[ E = \frac{IM - PI}{\sqrt{2}} \]

(Paas & van Merriënboer, 1993)

As shown in Table 3.1, mental effort and extraneous cognitive load, were measured using both the CLSRS (Paas, 1992) and the CLDS (Leppink et al., 2013) respectively.
Both measures were used because CLSRS has been used successfully for many years in CLT literature and data can be used to calculate learning efficiency; the more recent CLDS scale provides a more sensitive validated measure for the different types of cognitive load. This instrument allowed validation of experimental materials in terms of element interactivity (ICL) and CLT compliance (ECL).

Each experiment consisted of three phases. Participants were firstly provided with instructions for the experiment and an explanation of experimental materials. During phase two, participants completed demographic questions and completed the AMAS for determination of baseline maths anxiety (Part 1). The final phase consisted of completion of maths tasks and questionnaires (Part 2). In experiments 1 and 2, part 2 consisted of three sections, where participants completed problems of low, moderate and high element interactivity. In experiment 3, part 2 consisted of 2 sections, where participants completed problems of low and high element interactivity. These problems presented to participants were designed as either CLT compliant instructional materials (with paired process-oriented worked examples) or CLT non-compliant instructional materials (with product-oriented worked examples with evident split attention effects and conventional problems to solve). The level of difficulty of questions in each experiment was adjusted according to the students’ level of expertise. Maths content used in the experiments was consistent with work previously covered by participants. This eliminated the need for a pre-training session to effectively manage complex material in the experiment (Pollock et al., 2002). In addition, previously learned materials resulted in freeing up working memory resources due to the prior knowledge of the learner, and development of expertise for some participants. Previous cognitive load theory research has used novel content, which results in processing limitations in working memory due to the absence of relevant schemas in LTM. As such, this research eliminated limitations associated with the measurement of cognitive load associated with a task due to the overwhelming nature of complex novel material being used (particularly for novices), common in previous CLT research (Kirschner, Sweller & Clark, 2006). Each set of questions was followed by an identical short questionnaire where participants provided subjective ratings of dependent variables shown in Table 3.1.
3.2.3 Data Analysis

The data analysis strategies for Experiments 1, 2 and 3 were similar. Analysis of participants’ performance and subjective measures of cognitive load across the instructional conditions was undertaken by conducting a 2 (Instructional Design Condition) x 2/3 (Element Interactivity Condition) factorial analysis. This was followed by analysis using Pearson’s Correlation coefficient to investigate the relationship between participant baseline maths anxiety and cognitive load regardless of instructional condition, then across conditions using a 2 (Instructional Design Condition) X 2 (Baseline Maths Anxiety) ANOVA. Part 3 considered participant’s baseline maths anxiety in the analysis of performance scores, subjective measures of cognitive load and perceived task anxiety and additional dependent variables as necessary (for example, expertise due to its impact on cognitive load and element interactivity). This analysis was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2/3 (Element Interactivity Condition) factorial analysis. Any of the above analyses that indicated significant effects related to element interactivity, instructional design conditions and baseline maths anxiety were further analysed using 2 (experimental group) or 2/3 (level of element interactivity) x 2 (dependent variable) ANOVA, t-tests and Cohen’s d. This was done in order to highlight specific details associated with the results between two experimental groups or at different levels of element interactivity. Where several t-tests were performed to follow up an ANOVA, post-hoc testing was carried out using pairwise/multiple comparisons of estimated marginal means with Bonferroni adjusted alpha levels indicating significance at the 0.05 level.

3.3 SUMMARY OF RESEARCH DESIGN

Experiments 1, 2 and 3 were a between subjects design. Each of the 3 experiments examined to performance, cognitive load, and perceived task anxiety of mathematics students. In experiments 1 and 2, participants were required to solve fifteen algebra mathematics problems of varying levels of element interactivity (5 of low, 5 of moderate and 5 of high element interactivity). A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial
experimental design was implemented. Analysis focused on tasks of high element interactivity only. In Experiment 3, participants were required to solve a series of twenty algebra mathematics problems of low or high element interactivity (10 of low element interactivity followed by 10 of high element interactivity). A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2 (Element Interactivity Condition) factorial experimental design was implemented. Analysis for Experiment 3 included tasks of both low and high element interactivity. The following three chapters explain further details of the methodology for each experiment specifically, as well as findings for Experiments 1, 2 and 3.
4 EXPERIMENT 1

4.1 INTRODUCTION

The overall aim of Experiment 1 was to investigate whether CLT compliant instructional materials, that is, worked examples, could support learners with high mathematics anxiety in a secondary school context to solve complex algebra problems. Worked examples are commonly used in classroom mathematics instruction and “the worked example effect is the best known and most widely studied of the cognitive load effects” (Sweller, 2006, p. 165). The Worked Example Effect has been previously shown to be present only when element interactivity is high, as a result of the complexity and associated high cognitive load on working memory (Leahy & Sweller, 2005). The use of worked examples when solving high element interactivity tasks reduces the load imposed by the task on working memory. The specific focus of this experiment was fourfold:

1. To confirm previous research that has shown that learners perform better and report lower cognitive load for tasks of high element interactivity when presented with instructional materials designed in accordance with the principles of cognitive load theory (CLT) than when presented with instructional materials not designed in accordance with CLT principles (see Research Question 1).

2. To investigate the relationship between learner anxiety and cognitive load. This relationship has not been investigated in previous research, thus the association between these two measures was examined for participants with both low and high baseline maths anxiety, regardless of instructional condition, for tasks of low, moderate and high element interactivity (see Research Question 2).

3. To examine whether worked examples assist learners with high mathematics anxiety when solving maths problems of high element interactivity by improving performance scores and reducing cognitive load (see Research Questions 3 and 4 and Exploratory Question 1).

4. To examine whether worked examples assist learners with high mathematics anxiety when solving maths problems of high element interactivity by reducing perceived task anxiety. Learners may experience higher levels of anxiety when
completing complex tasks, that is, for tasks of high element interactivity compared to tasks of low element interactivity. In this case, with the provision of CLT compliant instructional materials, and the associated reduction in extraneous cognitive load, a participant’s anxiety may be alleviated (see Exploratory Research Question 2).

The research questions and associated alternative hypotheses investigated were as follows:

RQ1: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

H1: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

H2: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

RQ2: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?

H3: Participants with high baseline mathematics anxiety will report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety.
**RQ3:** When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

**H₄:** When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load and greater investment of germane resources afforded by CLT compliant instructional materials.

**RQ₄:** When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower extraneous cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

**H₅:** When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials.

The Exploratory Research Questions being investigated were:

**EQ₁:** When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials?

**EQ₂:** When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional
materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

4.2 METHODOLOGY

4.2.1 Research Design

This experiment used a between subjects design to examine performance, cognitive load, and perceived task anxiety of secondary school students when solving fifteen algebra mathematics problems. A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial experimental design was implemented.

The independent variables were as follows:

1. Instructional Design Condition: Instructional materials designed as either CLT compliant or CLT non-compliant (explained below)
2. Baseline maths anxiety: Participants were identified with either high mathematics anxiety or low mathematics anxiety based on the Abbreviated Maths Anxiety Scale (see section 4.3.4)

CLT compliant instructional materials were presented as paired worked examples. That is, each mathematics problem to be solved was preceded by a process-oriented worked example similar to the one to be solved (see Figure 4.1). Problems were presented in order of increasing complexity, that is, 5 low, 5 moderate and 5 high in element interactivity. The CLT non-compliant instructional materials were presented as problems in order of increasing difficulty to be solved (see Figure 4.2) and eight product-oriented worked examples were provided separately on an accompanying sheet creating a split attention effect. The worked examples represented problems of low, moderate and high element interactivity but were not presented in that order. Thus the evident split attention effect as a result of search and match processes associated with
presentation of worked examples not appropriately integrated with problems to be solved was what constituted ‘CLT non-compliance’ (Chandler & Sweller, 1992). The instructional materials are explained in more detail in Sections 4.2.3 and 4.2.4 below.

The dependent variables were as follows:
1. Performance on mathematics tasks;
2. Cognitive load / mental effort measured subjectively using two scales:
   (i) The Cognitive Load Subjective rating Scale (CLSRS) (Paas, 1992),
   (ii) Cognitive Load Differentiating Scale (CLDS) differentiating between intrinsic (ICL), extraneous (ECL) and germane cognitive load (GCL) scales (Leppink et al., 2013);
3. Subjective measure of perceived task anxiety (Baloglu and Zelhart, 2007);
4. Completion time for algebra tasks in each Section, A, B and C;
5. Perceived task difficulty, task importance, task engagement and task satisfaction. Participants reported subjective ratings of the factors following completion of algebra tasks in each Section, A, B and C.

Subjective measures of cognitive load have undergone considerable examination in cognitive load research. Following the crucial development of the CLSRS (Paas, 1992), an instrument providing reliable and valid measurement of cognitive load, this nine point subjective rating scale has been used extensively to measure mental effort. A number of studies have used measures of task difficulty in place of mental effort (Marcus, Cooper, Sweller, 1996). The subjective ratings provided by measures of task difficulty have been shown to vary from measures of mental effort (Cierniak et al., 2009; van Gog et al., 2008). Furthermore, cognitive load research has attempted to measure various components of cognitive load (Ayres, 2006a; Cierniak et al., 2009). This led to the development of what is referred to in this research as the CLDS (Leppink et al., 2013), which measures ICL, ECL and GCL separately using an 11-point scale. Additional variables listed in item 5 above have been included to provide a possible explanation for participants’ responses related to mental effort and individual components of cognitive load. These responses were measured on a 9-point scale to provide consistency with the CLSRS. Recent research has similarly developed scales
with additional items, in order to consider such participant responses when considering these measures.

4.2.2 Participants

Seventy-one students (34 males and 37 females) from an urban co-educational independent school in NSW, Australia participated in the study. Participants in this study were secondary maths students aged 15 -16 years studying Stage 5 (Academic Years 9 and 10) mathematics. All students were currently in Year 10 enrolled in an Advanced, Intermediate or Standard Mathematics course based on NSW syllabus requirements. Students in Advanced Mathematics work towards completion of syllabus outcomes for Stage 5.1, 5.2 and 5.3; those undertaking Intermediate Mathematics complete syllabus outcomes for Stage 5.1 and 5.2 and those students undertaking Standard Mathematics complete syllabus outcomes for Stage 5.1 during Year 9 and 10 only. All stages cover content from Number and Algebra, Measurement and Geometry, and Statistics and Probability. The content in each stage increases in difficulty and complexity from Stage 5.1 to 5.3, with the advanced course the most abstract of the three courses in all content areas (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-k10/).

Independent testing of students’ mathematical ability was not conducted because all students were rated by the school and streamed according to mathematical ability into Advanced, Intermediate or Standard maths classes on the basis of on-going school assessment. This criterion was used to split students into groups of “experts” or “novices” for additional data analysis found in Sections 4.4.3.2.3 and 4.4.3.4.1. Students enrolled in advanced maths were considered experts, and those students enrolled in intermediate or standard maths were considered novices.

The experiment was conducted in one session during a 90-minute lesson at the end of Term 2 of a four-term year. Ethics approval for the experiment was received from the University of Wollongong Human Research Ethics Committee (see Appendix A). Prior to conducting the experiment, two meetings were held with relevant teaching staff, consisting of Head of Mathematics and Year 10 classroom teachers. In the first meeting
teachers confirmed the content in the instructional materials had been covered in class and thus the level of difficulty aligned with the students’ ability across the year group. Consent and Participant information sheets were provided for distribution to parents and participants (See Appendices F and G). In the second meeting, teaching staff involved were provided with information regarding the purpose of the study, the relevance of the research in terms of optimal instructional design for learners with high maths anxiety and specific instructions for conducting the experiment (See Appendices H and I).

4.2.3 Instructional Materials

The instructional materials were designed as either CLT compliant or CLT non-compliant. These two instructional design conditions are explained in detail as follows.

**CLT Compliant Condition**

Participants in this condition \( n = 36; 15 \text{ males}, 21 \text{ females} \) were provided with CLT compliant instructional materials consisting of worked examples paired with each of the conventional algebra problems to be solved. The worked examples were process-oriented worked examples, where the key processes in each worked example were highlighted and an explanation of the procedure was written next to each step (see Figure 4.1). The worked examples were incorporated into the worksheet in order to avoid split attention effects. The experimental materials are explained in more detail in the next section and the complete set of materials for the CLT compliant condition can be found in Appendix B.
Figure 4.1. Sample worked example and problem to solve of low element interactivity from CLT compliant instructional materials.

**CLT non-Compliant Condition**

Participants in this condition \((n = 35; 19\) male, 16 female) were provided with cognitive load theory non-compliant instructional materials where they were required to solve the same mathematics problems as in Condition 1 but each problem was presented as a conventional problem to solve, as shown in Figure 4.2.
Unlike the CLT compliant condition, instructional materials in the CLT non-compliant condition did not contain worked examples paired with each problem to be attempted. Instead, a separate white A4 sheet of paper was distributed with eight generic product-oriented worked examples to which participants were able to refer as a guide for solving the conventional algebra problems. These worked examples were considered as product-oriented worked examples as the rationale behind each step in the worked example was not provided. The worked examples did not have highlighting or written explanations as provided in the process-oriented worked examples in the CLT compliant condition. A product-oriented worked example is provided in Figure 4.3.

![Image of worked example](image_url)

**Figure 4.2.** Sample problem to solve of low element interactivity from CLT non-compliant instructional materials.

**Figure 4.3.** A sample of a non-paired product-oriented worked example from the separate A4 sheet accompanying CLT non-compliant instructional materials.
According to research by van Gog et al. (2008), product-oriented worked examples are inferior in design to process-oriented worked examples due to the absence of instructional explanations and without structural features highlighted. Also, the provision of worked examples distributed on a separate sheet was a source of split attention for participants in the CLT non-compliant condition. Participants were required to search for the appropriate worked example for the maths problem being attempted and participants were required to move back and forth between the worked examples provided on the separate sheet and the problems to be solved in the instructional booklet. In addition, the worked examples were not paired with specific problems to be solved, nor were they presented in order of increasing complexity. These factors collectively contributed to the CLT non-compliance of the instructional materials, differentiating them from the instructional materials used in the CLT compliant condition. Experimental materials are explained further in the next section and a complete set of materials for the CLT non-compliant condition is presented in Appendix C. The separate sheet of product-oriented worked examples is presented in Appendix D.

4.2.4 Experimental Materials

The instructional materials consisted of a total of 15 algebra problems (5 questions of low element interactivity, 5 questions of moderate element interactivity and 5 questions of high element interactivity) that were designed for students working towards completion of Stage 5 Mathematics outcomes from the Patterns and Algebra Strand of the NSW Education Standards Authority Mathematics K-10 Syllabus (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-k10/). As stated previously, the level of difficulty of the algebra problems was made in consultation with the students’ classroom teachers to ensure pre-requisite algebra content had been covered in class and was of a suitable level of difficulty and were aligned with the NSW Mathematics Syllabus. Questions with low element interactivity consisted of one or two solution steps, questions of moderate element interactivity involved three or four solution steps and high element interactivity solutions were comprised of four or five solution steps.
Unlike previous research associated with CLT that introduces novel content to participants (Kester, Kirschner & van Merriënoer, 2005; Paas, van Gerven & Wouters, 2007), the rationale for this experiment was to use content previously learnt by participants in order to investigate the relationship between anxiety, element interactivity and CLT compliant instructional materials. This eliminated the need for a pre-training phase, introduced into cognitive load research to alleviate negative effects associated with the use of complex novel content (Pollock et al., 2002). Teaching staff confirmed the instructional materials comprised content previously taught in class, therefore it was not considered necessary for pre-training on the algebra content, which was the focus of the experiment. However, without pre-testing of participants, any prior knowledge cannot be assumed to be the same for all participants, thus there may be a variation in the level of expertise of participants. For example, participants enrolled in Advanced Mathematics would have developed greater expertise than those enrolled in Intermediate Mathematics, who, in turn, would have greater expertise than those participants enrolled in Standard Mathematics. Those students in Standard Mathematics, although familiar with the algebra content, are more likely to be novices in terms of acquisition of relevant schema. Students enrolled in Advanced Mathematics (classes 1-3 in the year) were considered experts in this domain for purpose of the study, and students enrolled in Intermediate or Standard Mathematics (classes 4-7 in the year) were considered novices.

Algebra problems of low, moderate and high element interactivity were included in the instructional materials in order to investigate the worked example effect and the cognitive load for students with high mathematics anxiety. In addition, it should be noted that element interactivity may be considered subjective, as the level of expertise varies amongst participants. The level of expertise of a participant may impact the level of element interactivity of a task (Kalyuga, 2007). This variation exists as a result of previous exposure to the content covered in the task. Expertise involves an increase in the number and complexity of domain specific schema, that is, both the quantity and quality of schemas relevant to a particular task. This allows tasks to become automated, reducing the load on working memory (Chase & Simon, 1973). As such, the cognitive load associated with a task may be significantly reduced for experts compared to
novices. When investigating cognitive load, it therefore becomes relevant to have some understanding of the level of expertise of learners.

The experimental materials were comprised of two booklets, one for the CLT compliant condition and one for the CLT non-compliant condition. The Experimental Materials consisted of two parts:

Part 1 measured participant’s baseline mathematics anxiety using the Abbreviated Mathematics Anxiety Scale (AMAS). All participants completed the scale in order to determine their baseline level of mathematics anxiety. The scale consists of 9 questions answered on a Likert scale ranging from 1 to 5, where a value of 1 represents low anxiety, 2 some anxiety, 3 moderate anxiety, 4 quite a bit of anxiety and 5 represents high anxiety (See Appendices B and C). The scores were added to provide a total anxiety score, with a minimum possible score of 9 and a maximum possible score of 45 for each participant. This scale was constructed and validated by Dr Derek Hopko. Permission to use the scale was requested and received from Dr Derek Hopko (see Appendix E1).

Part 2 included the instructional materials, as well as measures of the dependent variables: performance on algebra tasks, cognitive load, anxiety, task completion time and other participant reactions to the task, including task difficulty, importance, satisfaction and engagement. At the beginning of the booklet, participants were given written instructions and asked to provide demographic information, which included age, gender and maths class (indicative of expertise).

Part 2 comprised three sections: Section A, Section B and Section C. Each section had the same structure and consisted of five algebra problems followed by a questionnaire for participants to complete. The only difference between each section was the level of complexity of the algebra problems to be solved. Element interactivity increased as the participant progressed through each section. The algebra problems in Section A were of low element interactivity, in Section B were of moderate element interactivity and in Section C were of high element interactivity. Participants recorded their personal start and finish time for each section using their own stopwatch or the clock in classroom. No
time constraints were imposed so as not induce any potential additional anxiety. In total, participants completed 15 problems (5 each of low, moderate and high element interactivity) and 3 measures of cognitive load and anxiety (1 each following low, moderate and high element interactivity problems) during the testing phase. Part 2 provided data on performance on mathematics problems, as well as mental effort / cognitive load and task anxiety from subjective responses to questions by low and high anxious learners.

Section A consisted of a set of five mathematics problems of low element interactivity. A maximum score of 10 was possible for a participant’s performance in each section. For each problem, two marks were allocated for a correct response, one mark was allocated for a response with either an incorrect sign or a minor arithmetical error in the final step and no marks were awarded for all other responses. Section B consisted of a set of 5 mathematics problems of moderate element interactivity and Section C consisted of a set of 5 mathematics problems of high element interactivity respectively. Again, a maximum score of 10 was possible for a participant’s performance in each section. Marking criteria was consistent with that used for Section A. Participants recorded their start and finish time for the set of five algebra problems solved in each section.

The five algebra problems to be solved in each section were followed by an identical short questionnaire which participants were required to complete. These questions provided subjective feedback regarding task difficulty, mental effort, and anxiety related to the task. The questionnaire following each set of maths questions consisted of 2 instruments:

1. Two items based on the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992), which were answered on a 9-point Likert Scale. Participants rated the following from 1 (extremely low) to 9 (extremely high):
   - The mental effort required to complete the task,
   - The difficulty of the task.

Permission to use the scale was requested and received from creator, Dr Fred Paas (See Appendix E2).
A further four items were included in this section and for ease of completion and consistency, were identical in structure to the items based on the CLSRS. The first of these items was a subjective measure of anxiety related to each task adapted from a scale used in research conducted by Baloglu and Zelhart (2007). Participants rated the following from 1 (extremely low) to 9 (extremely high):

- The level of anxiety experienced while completing the task.

Permission to use the scale was requested and received from Dr Mustafa Baloglu, responsible for development of the scale (See Appendix E3).

The final three items were subjective measures related to the task completed. These items were chosen due to their potential relationship with participant’s perceived load, anxiety and performance on a task. Participants rated the following from 1 (extremely low) to 9 (extremely high):

- The level of satisfaction with performance on a task,
- The level of importance placed on the task,
- The level of engagement experienced while completing the task.

2. Ten items based on the recently developed instrument for measuring different types of cognitive load, referred to here as the Cognitive Load Differentiating Scale (CLDS) (Leppink et al., 2013), which were answered on a 11-point Likert Scale ranging from 0 (not at all the case) to 10 (completely the case).

A measure of Intrinsic Cognitive Load (ICL) specifically was attained from the participant’s responses to items 1-3 (stated below) on the scale:

1. The topic covered in the task was very complex.
2. The task covered problems that I perceived as very complex.
3. The task covered concepts that I perceived as very complex.

Extraneous Cognitive Load (ECL) was calculated by the sum of the responses to items 4-6 (stated below) on the CLDS (Leppink et al., 2013) scale of cognitive load:

4. The instructions and/or explanations during the task were very unclear.
5. The instructions and/or explanations were, in terms of learning, very ineffective.
6. The instructions and/or explanations were full of unclear language.

Items 7-10 (stated below) in the Cognitive Load Differentiating Scale devised by Leppink et al. (2013) were designed to measure Germane Cognitive Load:
7. The task really enhanced my understanding of the topic covered.
8. The task really enhanced my knowledge and understanding of algebra.
9. The task really enhanced my understanding of the problems covered.
10. The task really enhanced my understanding of concepts.

Despite controversy surrounding the definition and measurement of germane cognitive load (Bergman et al., 2015; Leppink, et al., 2014), this terminology was retained in order to maintain consistency with the instrument used in this research. It is noteworthy recent research has interpreted this measure to more accurately represent “self-perceived learning” (Bergman et al., 2015) or “understanding” (Ayres, in press).

Dr Jimmie Leppink was responsible for the construction of this scale; permission to use the scale was requested and received (See Appendix E4).

4.2.5 Procedure

Participants were randomly assigned to one of two instructional design conditions (CLT compliant and CLT non-compliant). Random allocation to one of two conditions resulted from booklets handed out in random order whilst ensuring approximately even numbers of each booklet were distributed. The experiment was conducted for participants in both conditions at the same time. There were 3 phases to the experiment that are explained below. Participants were able to proceed at their own pace in Phases 2 and 3.

Phase 1: Introduction

Instructions were provided for participants verbally and on the front page of the booklet. A script was provided to each of the eight class teachers supervising the students to ensure instructions for each class were consistent (see Appendix I). Participants were
informed they were able to proceed at their own pace and were asked to record their start and finish time for each section of the maths problems using a watch or stopwatch on their phone, or the clock in the classroom. The booklets were to be completed in order and participants were asked not to go back and make any changes once each section was completed and the time was recorded. They were asked to complete all answers in the booklet provided and include all working steps in their solution for each problem. Participants were permitted to use calculators in order to minimise calculation errors and focus on the understanding of algebraic concepts. In addition, participants were assured that they were not being tested in any way and the worksheets completed would not form part of their assessment for their course. Once the instruction prior to the task was completed, no further verbal directions or feedback was provided to students. The researcher moved between classes continuously throughout the experiment to ensure classes progressed smoothly and consistently during the study.

Phase 2: Baseline measure of anxiety and demographic / expertise of participants
Participants completed the Abbreviated Mathematics Anxiety Scale (AMAS), to determine a baseline measure of anxiety (See Part 1, Appendices B and C). Participants’ level of anxiety was used to allocate participants to test groups. Mathematics ability was established according to data available from the school regarding participants’ level of mathematics expertise. It should be noted that expertise contributes to a reduction in cognitive load so this must be identified in order to isolate the effects of CLT compliant materials for anxious students.

Phase 3: Completion of Maths Tasks and Questionnaires
Instructional materials for this experiment were based on the Stage 5 outcomes of the NSW Mathematics syllabus. Participants were required to complete a worksheet (see Appendices B and C) that included a number of algebraic equations. A measure of the number of correct responses was made, and marks allocated according to the marking scheme outlined previously (see Section 4.2.4). Participants recorded their start and finish time for each set of algebra problems. Participants in both conditions completed the same questionnaires after the algebra questions in each section. To ensure confidentiality, data from each booklet was recorded, identifying the student as a participant in the CLT compliant condition or CLT non-compliant condition only.
4.3 DATA ANALYSIS

Data analysis consisted of two phases. The first phase consisted of preliminary analysis of data to determine inter-rater reliability, ensuring consistency of marking test items, followed by testing for normality of data, due to the small sample size. Participants were then identified as low baseline maths anxiety and high baseline maths anxiety in each Instructional Design Condition. The second phase of data analysis comprised the analysis of dependent variables, and consisted of three parts. Firstly, analysis of participants’ performance and subjective measures of cognitive load across the instructional conditions was undertaken by conducting a 2 (Instructional Design Condition) x 3 (Element Interactivity Condition) factorial analysis. This was followed by analysis using Pearson’s Correlation coefficient to investigate the relationship between participant baseline maths anxiety and cognitive load regardless of instructional condition, then across conditions using a 2 (Instructional Design Condition) X 2 (Baseline Maths Anxiety) ANOVA. Part 3 considered participant’s baseline maths anxiety in the analysis of performance scores, subjective measures of cognitive load and perceived task anxiety and additional dependent variables as necessary (for example, expertise due to its impact on cognitive load and element interactivity). This analysis was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial analysis.

An elaboration of how these two phases of data analysis were conducted is provided below.

4.3.1 Preliminary Analysis

Inter-rater reliability
Two independent scorers marked all participant booklets. Both scorers awarded marks according to the criteria provided (refer to Section 4.2.4). On completion of marking, a comparison of the marks allocated by the two independent scorers was undertaken to examine consistency and accuracy of results by calculation of Pearson Correlation.
Results demonstrated an inter-rater reliability $r = 1$, indicating a perfect correlation between markers (Gao, 2012). In addition, to assess systematic differences in scores from each marker, the intraclass correlation coefficient (ICC) was also calculated. The ICC assesses the consistency of quantitative measurements, such as performance scores, made by different markers of the same questions and is a more accurate measure of variability in scores. A measure of 1 for both Cronbach’s alpha and ICC suggests consistency and accuracy between scorers for all test items.

**Normality of Data**

As normality is an assumption of many tests performed in parametric measures, the normality of the data was tested using the Shapiro-Wilk test. A frequency distribution polygon representing the total AMAS scores for participants in both instructional design conditions, CLT compliant and CLT non-compliant is provided in Figure 4.4. The visual representation of scores indicated a normal distribution of maths anxiety for both conditions.

![Figure 4.4](image-url)

*Figure 4.4.* Frequency polygon representing normal distribution of AMAS scores in both instructional design conditions.

Normality of data was tested using the Shapiro-Wilk test. This test confirmed normality for the AMAS and some cognitive load measures for both the CLT compliant and CLT non-compliant group (see Table 4.1).
Table 4.1

Normality Of Data Under Each Condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Variable</th>
<th>SW Statistic</th>
<th>SW df</th>
<th>SW Sig.</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT compliant</td>
<td>AMAS</td>
<td>.965</td>
<td>34</td>
<td>.343</td>
<td>✓</td>
</tr>
<tr>
<td>Low Element Interactivity</td>
<td>Performance</td>
<td>.474</td>
<td>34</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.982</td>
<td>34</td>
<td>.845</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.864</td>
<td>34</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Moderate Element Interactivity</td>
<td>Performance</td>
<td>.860</td>
<td>34</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.962</td>
<td>34</td>
<td>.282</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.922</td>
<td>34</td>
<td>.019</td>
<td>✓</td>
</tr>
<tr>
<td>High Element interactivity</td>
<td>Performance</td>
<td>.910</td>
<td>34</td>
<td>.009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.967</td>
<td>34</td>
<td>.381</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.980</td>
<td>34</td>
<td>.765</td>
<td>✓</td>
</tr>
<tr>
<td>CLT non-compliant</td>
<td>AMAS</td>
<td>.967</td>
<td>34</td>
<td>.378</td>
<td>✓</td>
</tr>
<tr>
<td>Low Element Interactivity</td>
<td>Performance</td>
<td>.481</td>
<td>34</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.981</td>
<td>34</td>
<td>.789</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.813</td>
<td>34</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Moderate Element Interactivity</td>
<td>Performance</td>
<td>.862</td>
<td>34</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.972</td>
<td>34</td>
<td>.531</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.920</td>
<td>34</td>
<td>.016</td>
<td></td>
</tr>
<tr>
<td>High Element Interactivity</td>
<td>Performance</td>
<td>.860</td>
<td>34</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLSRS</td>
<td>.944</td>
<td>34</td>
<td>.083</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>CLDS</td>
<td>.971</td>
<td>34</td>
<td>.482</td>
<td>✓</td>
</tr>
</tbody>
</table>
The anxiety scores for each condition (CLT compliant and CLT non-compliant) on the AMAS were normally distributed. This enabled the comparison of the data for the two conditions, CLT compliant versus CLT non-compliant, according to levels of anxiety, that is, a high anxiety group and low anxiety group in each condition (see Table 4.1). Due to the small sample size, performance scores and some measures of cognitive load did not demonstrate normality. However, despite this, non-parametric tests were not required to be conducted on the data given the non-extreme asymmetry, skewness and outlier effect of the distribution (depicted in Figure 4.4) and it was unlikely to result in any variation with the parametric tests. This ensured parametric tests would still provide valid results for this non-normal continuous data, with parametric tests being preferable given they “are slightly more powerful than nonparametric tests for normal or approximately normal distributions” (Zimmerman, 1998, p. 55). Parametric analyses were therefore conducted and are presented in these results.

**Exclusion of participants**

Three participants did not complete all sections of the worksheets. These participants were included in all phases of the experiment but their information was excluded from some data analysis. Two participants did not complete the AMAS (Part 1) and data included responses from these participants only when the anxiety condition was not incorporated into the analysis. Another participant did not complete the maths questions with high element interactivity in Section C of Part 2 due to time constraints. Only data from Section A and B (from Part 2) of the worksheets for this participant was included in analysis.

**Identifying high and low anxious participants**

Participants received either CLT compliant experimental materials or CLT non-compliant experimental materials. An individual’s baseline level of anxiety was calculated and identified according the Abbreviated Maths Anxiety Scale (AMAS). Each individual’s score was composed of the sum of their subjective responses to 9 questions to provide a total anxiety score with a minimum of 9 and maximum of 45 possible (Hopko et al., 2003a). The group to which participants were assigned was determined firstly by their random allocation to an instructional condition and secondly...
by their baseline maths anxiety determined by their AMAS score. A total of four groups emerge for Part 3 of the analysis of dependent variables (see Figure 4.5).

Figure 4.5. Organisation of participants into four groups for Part 3 of data analysis.

The anxiety scores for this experiment were analysed using two techniques used in recent literature. Using the first technique, participants were categorised as high anxiety when their score lies 1 standard deviation above the mean, and low anxiety when their score is 1 standard deviation below the mean (Ashcraft & Moore, 2009; Hopko, Ashcraft, Gute, Ruggiero & Lewis, 1998). When considering groups one standard deviation above and below the mean, a sample size of 6 (CCLA, CCHA, CNHA) and 8 (CNLA) for each group was achieved. AMAS scores for CCLA were those below 19, for CCHA were those above 30, for CNLA were those below 17 and for CNHA were those above 25. Using the second technique, participants were categorised as high anxiety when their AMAS score was positioned in the upper quartile of scores, and low anxiety when their score was positioned in the lowest quartile of scores (Maloney, Risko, Ansari & Fugelsang, 2010). When participants were divided into quartiles, the sample size for each group was 9. AMAS scores for CCLA were those below 22, for CCHA were those above 27, for CNLA were those below 19 and for CNHA were those above 23. Both techniques resulted in a small sample size for groups representing CLT
compliant low and high anxiety and CLT non-compliant low and high anxiety. As the use of quartiles and descriptive statistics to determine cut-off scores for high and low maths anxious individuals are arbitrary techniques, terciles were used in this case to determine low and high anxiety groups.

In order to maximise the sample size for this experiment, participants were divided into three groups and categorized as low or high maths anxious based on the scores obtained on the AMAS. High maths anxious individuals were those with AMAS scores in the top third of scores in each condition and low maths anxious individuals were those with AMAS scores in the bottom third of scores for each condition. Individuals in the middle third were not included in analysis for anxiety groups. Using this criterion to categorise participants, an independent samples t-test was conducted to compare the AMAS scores of those with low and high anxiety in the CLT compliant condition and the AMAS scores of those with low and high anxiety in the CLT non-compliant condition. There was a significant difference in the scores for low anxiety (\(M = 19.43, SD = 3.72\)) and high anxiety (\(M = 29.92, SD = 3.70\)) in the CLT compliant condition: \(t(24) = 7.19, p < .001\). There was also a significant difference in the scores for low anxiety (\(M = 17.67, SD = 1.95\)) and high anxiety (\(M = 26.17, SD = 2.66\)) in the CLT non-compliant condition: \(t(25) = 9.59, p < .001\). Those with scores identical to the cut-off were included: those included in each group were extended beyond the limits of the terciles to include an additional 2 participants in the low anxiety CLT compliant group and an additional 3 participants in the low anxiety CLT non-compliant group.

Table 4.2 illustrates the AMAS scores for all participants in both the CLT compliant and CLT non-compliant instructional materials conditions. Scores range from 10 to 40 for the CLT compliant condition and 14 to 31 for the CLT non-compliant condition. These scores were then divided into terciles. High and low anxious participants were therefore identified not solely on their AMAS score, but where that score placed them within the range of scores for individuals in the same condition. Responses determined whether participants were categorized as low or high anxiety maths individuals. Following analysis of the data collected, highly anxious participants were identified as those in the upper tercile of anxiety scores in each condition: 24 participants from a total of 71. This translated to AMAS scores of between 27 and 40 for the CLT compliant
instruction group and between 23 and 31 for the CLT non-compliant instruction group, a total of 12 participants in each. There were 29 participants identified as low anxious. Low anxious participants were identified as those in the lower tercile of anxiety scores in each condition. This translated to AMAS scores of between 10 and 23 for the CLT compliant instruction group and between 14 and 20 for the CLT non-compliant instruction group – a total of 14 and 15 participants respectively. The higher number of participants included in each tercile is a result of the addition of participants scoring the same as the cut-off point beyond the tercile limits.

Table 4.2  
Baseline AMAS Scores For Participants In Each Condition Identifying Upper And Lower Terciles.

<table>
<thead>
<tr>
<th>AMAS Score For Each Condition</th>
<th>CLT compliant</th>
<th>CLT non-compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Anxiety (LA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Tercile Range</td>
<td>10-23</td>
<td>14-20</td>
</tr>
<tr>
<td>LA n</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>LA Mean</td>
<td>19.43</td>
<td>17.67</td>
</tr>
<tr>
<td>LA Standard Deviation</td>
<td>3.72</td>
<td>1.95</td>
</tr>
<tr>
<td>Moderate Anxiety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Tercile Range</td>
<td>24-26</td>
<td>21-22</td>
</tr>
<tr>
<td>n</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>High Anxiety (HA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA Upper Tercile Range</td>
<td>27-40</td>
<td>23-31</td>
</tr>
<tr>
<td>HA n</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>HA Mean</td>
<td>29.92</td>
<td>26.17</td>
</tr>
<tr>
<td>HA Standard Deviation</td>
<td>3.70</td>
<td>2.66</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Range</td>
<td>10-40</td>
<td>14-31</td>
</tr>
<tr>
<td>Total n</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Total Mean</td>
<td>24.63</td>
<td>21.46</td>
</tr>
<tr>
<td>Total Standard Deviation</td>
<td>5.498</td>
<td>4.250</td>
</tr>
</tbody>
</table>

80
Within each condition, anxiety scores are low or high relative to others in that group only, not necessarily relative to low or high baseline anxiety measures of participants in the other group. Despite random allocation of participants to each condition, the upper and lower boundaries of the anxiety scores were different for the CLT compliant and CLT non-compliant condition (refer to Table 4.2 Tercile). The baseline maths anxiety level (AMAS) of those participants in the CLT compliant condition \((M = 24.63, SD = 5.58)\) was higher than the CLT non-compliant condition \((M = 21.46, SD = 4.31)\). That is, there were more highly anxious students in the CLT compliant condition (refer to Table 4.2 Means). A t-test revealed a significant difference in the baseline maths anxiety measure of participants in each condition, \(t(66) = 2.590, p = .012\). Participants in the CLT compliant condition had significantly higher baseline anxiety scores than participants in the CLT non-compliant condition.

4.3.2 Analysis of dependent variables

The second phase of data analysis was the analysis of dependent variables. Overall, there were three parts to this analysis. All analyses were preceded by computation of descriptive statistics (mean, standard deviation) for all measures of performance, cognitive load and anxiety. Part 1 consisted of a 2 (Instructional Design) x 3 (Element Interactivity) analysis of variance (ANOVA) for performance and cognitive load measures to investigate any differences between the two conditions, CLT compliant and CLT non-compliant, at three levels of element interactivity (low, moderate, and high). This analysis was undertaken to confirm relevant aspects of previous research related to the effectiveness of CLT compliant instructional materials at varying levels of element interactivity prior to the inclusion of anxiety as a variable. Part 2 involved investigation of the correlation between each participant’s baseline maths anxiety and cognitive load. Analysis was conducted using Pearson’s Correlation coefficient to determine the nature of this relationship at different levels of element interactivity regardless of the instructional condition, that is, while using either CLT compliant instructional materials or CLT non-compliant instructional materials. Results were further investigated with a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) ANOVA to confirm findings across instructional design conditions. In Part 3, analysis considered participant’s baseline maths anxiety and results were examined based on low and high
anxiety groups in addition to the instructional condition. This analysis comprised a 2 (Instructional Design) x 2 (Baseline Anxiety) x 3 (Element Interactivity) analysis of variance (ANOVA) of participants’ performance scores, cognitive load ratings and perceived task anxiety ratings. Any of the above analyses that indicated significant effects related to element interactivity, instructional conditions and baseline maths anxiety were further analysed using 2 (experimental group or level of element interactivity) x 2 (dependent variable) ANOVA, t-tests and Cohen’s d. This was done in order to highlight specific details associated with the results between two experimental groups or at two different levels of element interactivity. T-tests were conducted using a Bonferroni correction to the alpha-level of 0.05 according to the number of tests conducted in order to control the Type I error rate associated with multiple comparisons. Cohen’s d indicates the importance of an effect, a value of 0.2 representing a small effect size, 0.5 representing a medium effect size and 0.8 representing a large effect size (Cohen, 1992). Additional findings related to participants’ performance, cognitive load and perceived task anxiety in terms of expertise was conducted and is discussed in Sections 4.4.3.2.3 and 4.4.3.4.1. In addition, descriptive statistics for task completion time and for participants’ subjective ratings of task difficulty, task importance, task satisfaction and task engagement were analysed. A full set of these results can be found in Appendix J (Table J1). These were reported for each section following completion of each set of maths questions and subjective ratings were measured using the same 9-point likert scale as the Cognitive Load Subjective Rating Scale. In addition, efficiency measures for low, moderate and high element interactivity tasks were calculated. Details of additional findings related to these variables are found in Appendix J.

4.4 RESULTS

The results are presented in three parts according to the research questions, and as discussed in Section 4.3.2. Analyses of variables beyond those addressed specifically in the research questions have been included as additional findings as appropriate, with full details of the analyses for these additional findings available in Appendix J.
4.4.1 Part 1 – Performance and Cognitive Load across Instructional Conditions

Research Question 1 was concerned with a comparison of participants’ performance scores and ratings of cognitive load for problems of high element interactivity when using either CLT compliant instructional materials or CLT non-compliant instructional materials. This analysis was undertaken to confirm previous research findings related to the negative impact of CLT non-compliant instructional materials and tasks of high element interactivity on participants’ performance scores and subjective ratings of cognitive load. Analysis did not include consideration of participants’ level of mathematics anxiety in Research Question 1.

4.4.1.1 Performance across Instructional Conditions

Performance scores were calculated for low, moderate and high element interactivity, each consisting of 5 questions and with a possible maximum score of 10, combining to give a total score out of 30. Descriptive statistics for performance scores in the CLT compliant condition and CLT non-compliant condition are shown in Table 4.3.

Table 4.3
Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Condition

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>CLT compliant $n = 36$</th>
<th>CLT non-compliant $n = 35$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performance Mean (SD)</td>
<td>Performance Mean (SD)</td>
</tr>
<tr>
<td>Low (/10)</td>
<td>9.39 (1.52)</td>
<td>9.51 (1.25)</td>
</tr>
<tr>
<td>Moderate (/10)</td>
<td>7.17 (2.17)</td>
<td>6.77 (2.35)</td>
</tr>
<tr>
<td>High (/10)</td>
<td>5.72 (2.94)</td>
<td>4.43 (3.41)</td>
</tr>
<tr>
<td>Total (/30)</td>
<td>22.28 (5.50)</td>
<td>20.71 (5.78)</td>
</tr>
</tbody>
</table>

Overall, the total performance score for the CLT compliant condition and the CLT non-compliant condition were not statistically significant, $F(1,69) = 1.364, p = .247$. 
**Performance Scores and Element Interactivity**

Although the mean differences in performance scores favoured the CLT compliant condition, there were no significant differences in performance scores between the CLT compliant condition and the CLT non-compliant condition for tasks of low ($F(1,69) = 0.144, p = .705$), moderate ($F(1,69) = 0.542, p = .464$) or high ($F(1,69) = 2.937, p = 0.058$) element interactivity. At higher levels of element interactivity performance scores were lower for both the CLT compliant condition and the CLT non-compliant condition. For the CLT compliant condition, there was a significant difference between performance scores at low and moderate element interactivity, $t(33) = 6.647, p < .001$ and at moderate and high element interactivity, $t(33) = 3.334, p = .002$. For the CLT non-compliant condition there was a significant difference between performance scores at low and moderate element interactivity, $t(33) = 6.609, p < .001$ and at moderate and high element interactivity, $t(33) = 5.366, p < .001$. This finding therefore shows that performance scores were significantly higher for tasks of low element interactivity compared to tasks of high element interactivity. This supports previous research that an increase in the level of element interactivity results in a concomitant reduction in performance scores (Sweller, 1994).

**4.4.1.2 Cognitive load across instructional conditions**

Participants’ ratings of cognitive load were measured using two scales. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992). Whereas the CLSRS measures overall total cognitive load, an alternate cognitive load measurement scale devised by Leppink et al., (2013) was specifically designed to differentiate individual components of cognitive load i.e. intrinsic, extraneous and germane cognitive load, representing the total cognitive load for each task. This study refers to this scale as the Cognitive Load Differentiating Scale (CLDS). The results for both subjective cognitive load rating scales are presented below.

**4.4.1.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992)**

Mean mental effort ratings were calculated for low, moderate and high element
interactivity using the CLSRS. A score between 1 and 9 was recorded on a likert scale for “Rate the mental effort required to complete the task”. Total mental effort ratings for each condition were calculated by addition of mean mental effort ratings for tasks of low, moderate and high element interactivity. Descriptive statistics for mental effort ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 4.4.

Table 4.4

Descriptive Statistics – Mental Effort Rating (CLSRS) for CLT compliant and CLT non-compliant Condition

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>CLT compliant n = 36</th>
<th>CLT non-compliant n = 35</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mental Effort Rating</td>
<td>Mental Effort Rating</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low (/9)</td>
<td>2.56 (1.46)</td>
<td>2.07 (1.16)</td>
</tr>
<tr>
<td>Moderate (/9)</td>
<td>4.28 (1.78)</td>
<td>4.14 (1.77)</td>
</tr>
<tr>
<td>High (/9)</td>
<td>5.88 (1.56)</td>
<td>6.16 (1.58)</td>
</tr>
<tr>
<td>Total (/27)</td>
<td>12.44 (4.03)</td>
<td>12.37 (3.77)</td>
</tr>
</tbody>
</table>

Table 4.4 shows that as the mean total subjective mental effort rating for each condition was similar; there was no statistically significant difference, $F(1,69) = 0.006, p = .937$.

**Mental Effort Rating and Element Interactivity**

There were no significant differences in mental effort ratings between the CLT compliant condition and the CLT non-compliant condition for tasks of low ($F(1,68) = 2.265, p = .137$), moderate ($F(1,69) = 0.050, p = .824$) or high ($F(1,69) = 0.476, p = .493$) element interactivity. Results showed that the perceived mental effort reported when solving problems of high element interactivity was higher than that reported when solving problems of low element interactivity, in both instructional conditions. T-tests were performed to determine whether these results were statistically significant when comparing mental effort ratings at low and high element interactivity. For the CLT compliant condition, there was a significant difference in mental effort ratings between low and high element interactivity, $t(68) = 9.440, p < .001$ ($d = 2.20$). For the non-CLT
compliant condition there was a significant difference in mental effort ratings between low and high element interactivity, $t(67) = 12.138, p < .001 (d = 2.95)$. Therefore, at higher levels of element interactivity, the effort, or load, associated with the task was greater. This supports previous research that asserts that a participant’s subjective rating of cognitive load is greater at high levels of element interactivity (Paas & van Merriënboer, 1993).

4.4.1.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

Ratings for each component of cognitive load were measured using the Cognitive Load Differentiating Scale (Leppink et al, 2013). Cognitive load ratings were recorded for solving maths problems of low, moderate and high element interactivity. The CLDS consists of 10 items: 3 related to intrinsic cognitive load (ICL), 3 related to extraneous cognitive load (ECL) and 4 related to germane cognitive load (GCL) (refer to section 4.2.4). Each item was measured using an 11-point likert scale ranging from 0 to 10. The total load for the task in each instructional condition was found by adding the cognitive load ratings for low, moderate and high element interactivity tasks, for each component of cognitive load. For the purposes of this analysis, results focused on Extraneous Cognitive Load only.

Three items measuring ECL were recorded using an 11-point likert scale ranging from 0 to 10, creating a possible total score between 0 and 30, with higher scores indicating a higher load. Descriptive statistics for ECL ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 4.5.
Table 4.5

Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Condition

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>CLT compliant n = 36</th>
<th>CLT non-compliant n = 35</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECL Rating</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low (/30)</td>
<td>4.14 (4.92)</td>
<td>4.49 (5.43)</td>
</tr>
<tr>
<td>Moderate (/30)</td>
<td>5.14 (4.63)</td>
<td>3.69 (4.73)</td>
</tr>
<tr>
<td>High (/30)</td>
<td>7.80 (6.72)</td>
<td>5.74 (6.19)</td>
</tr>
<tr>
<td>Total (/90)</td>
<td>16.61 (12.93)</td>
<td>13.91 (14.86)</td>
</tr>
</tbody>
</table>

Table 4.5 shows that the mean total ECL reported was higher for CLT compliant instructions compared to CLT non-compliant instructions. However, this difference was not significant, $F(68,1) = 0.915, p = .342$.

**ECL Ratings and Element Interactivity**

There were no significant differences in ECL ratings between the CLT compliant condition and the CLT non-compliant condition for tasks of low ($t(69) = 0.373, p = .710$), moderate ($t(69) = 1.181, p = .242$) or high ($t(68) = 1.331, p = .188$) element interactivity. This finding does not support previous research that suggests the use of worked examples in instructional materials (CLT compliant) reduces ECL (Paas et al., 2003b). In both the CLT compliant condition and the CLT non-compliant condition, participants’ ratings of ECL were greater at higher levels of element interactivity. For the CLT compliant condition, a change in element interactivity from low to high had a significant effect on participants’ rating of ECL, $t(69) = 2.71, p = .009$, with a medium effect size ($d = 0.62$). However, for the CLT non-compliant condition, a change in element interactivity from low to high did not have a significant effect on participants’ rating of ECL, $t(68) = 0.91, p = 0.370$, and there was a small effect size ($d = 0.21$). For both conditions, ECL ratings were highest for tasks of high element interactivity.
4.4.1.3 Summary of Part 1 Results

Results showed that participants achieved higher performance scores when solving problems of low element interactivity compared to high element interactivity. However, results showed that there were no significant differences in the performance scores for participants using CLT compliant materials compared to participants using CLT non-compliant materials. Hypothesis 1, learners using CLT compliant instructional materials will outperform learners using CLT non-compliant instructional materials when solving problems of high element interactivity, in accordance with previous CLT research, was not supported. As expected, results showed that participants reported lower cognitive load when solving problems of low element interactivity compared to high element interactivity. That is, the cognitive load associated with a task corresponds with the complexity of the task. However, results showed that there were no significant differences in the ratings of cognitive load for participants using CLT compliant materials compared to participants using CLT non-compliant materials. These findings are consistent when analysing mental effort ratings using the CLSRS (Paas, 1992) and subjective ratings of extraneous cognitive load from the CLDS (Leppink et al., 2013). Thus Hypothesis 2, that predicted learners using CLT compliant instructional materials would report lower cognitive load compared to learners using CLT non-compliant instructional materials when solving problems of high element interactivity, in accordance with previous CLT research, was not supported.

4.4.1.4 Additional Findings for Validation of Materials

As stated above, the CLDS also measured the intrinsic and germane components of cognitive load. Notably, the analysis of these results allowed validation of our experimental materials, ICL for determining levels of element interactivity and GCL for effectiveness of CLT compliant instructional materials. Differences were reported for ICL at low element interactivity compared to high element interactivity and for GCL in the CLT compliant condition compared to the CLT non-compliant condition. Descriptive statistics for these measures can be found in Appendix J (Table J2 and Table J3 respectively).
The difference in the overall ICL reported when using CLT compliant materials (Mean = 21.96) and CLT non-compliant materials (Mean = 25.24) was not significant, $F(68,1) = 0.704, p = .404$. This is to be expected given Intrinsic Cognitive Load refers to the load directly associated with the number and complexity of elements within a particular learning task, which is the same for participants in both conditions. However, participants in both conditions reported ICL was greater at high element interactivity than at moderate element interactivity, which in turn was higher than at low element interactivity. Analysis using t-tests and calculation of Cohen’s $d$ indicated an increase in element interactivity from low to high had a significant and large effect for both the CLT compliant condition, $t(69) = 8.65, p < .001 (d = 2.04)$ and the CLT non-compliant condition, $t(67) = 6.94, p < .001 (d = 1.69)$. This was expected as ICL is directly related to the level of element interactivity involved in a task. This confirms that the experimental instructional materials successfully differentiated between tasks of varying levels of element interactivity.

As shown in Figure 4.6, the use of CLT compliant instructional materials, and the expected reduction in ECL that accompanies their use, allowed a learner to engage germane resources when solving complex tasks.

![Germaine Cognitive Load](image)

*Figure 4.6. Germane cognitive load for CLT compliant and CLT non-compliant conditions.*

89
There was a significant difference between the level of GCL experienced by those in the CLT compliant condition and those in the non-CLT compliant condition at high element interactivity, $t(66) = 1.910, p = .060$. Analysis of participants’ subjective ratings of germane cognitive load indicated for both the CLT compliant condition and the CLT non-compliant condition, higher levels of element interactivity resulted in higher reported GCL ratings by all participants. For the CLT non-compliant condition, an increase from low to high element interactivity did not have a significant effect on participants’ GCL rating, $t(68) = 0.714, p = 0.477$, indicating a small effect size ($d = 0.17$). However, for the CLT compliant condition, an increase from low to high element interactivity had a significant effect on the reported GCL, $t(69) = 2.648, p = .010$, a medium effect size ($d = 0.61$). This suggests that when solving problems of high element interactivity, participants using CLT compliant materials were more likely to invest germane resources required to solve more complex tasks.

4.4.2 Part 2 - Relationship between Cognitive Load and Baseline Mathematics Anxiety

Part 2 of the analysis of dependent variables, which focused on addressing Research Question 2, investigated the relationship between participants’ cognitive load ratings and their baseline maths anxiety, indicated by their AMAS score. This analysis was conducted to determine whether participants with high baseline mathematics anxiety reported higher cognitive load than learners with low baseline mathematics anxiety.

Descriptive Statistics and effect sizes for the mental effort and cognitive load ratings reported for low and high anxiety participants at low and high element interactivity are presented in Table 4.6. Table 4.6 shows at high element interactivity, anxiety had a medium effect on participants’ mental effort ratings, intrinsic cognitive load and extraneous cognitive load. Analysis using a one-way ANOVA revealed that participants’ baseline maths anxiety had a significant effect on ratings of mental effort ($F(1,51) = 7.345, p = .009$) and extraneous cognitive load ($F(1,51) = 4.985, p = .030$) for tasks of high element interactivity.
Table 4.6
*Means, Standard Deviations And Effect Sizes For Cognitive Load Ratings.*

<table>
<thead>
<tr>
<th></th>
<th>Low Element Interactivity</th>
<th></th>
<th></th>
<th>High Element Interactivity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Anxiety</td>
<td>High Anxiety</td>
<td>Effect Size</td>
<td>Low Anxiety</td>
<td>High Anxiety</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>(d)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>(d)</td>
</tr>
<tr>
<td><strong>CLSRS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>2.16 (1.23)</td>
<td>2.50 (1.33)</td>
<td>0.27</td>
<td>5.26 (1.55)</td>
<td>6.42 (2.44)</td>
</tr>
<tr>
<td><strong>CLDS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICL</td>
<td>1.48 (2.06)</td>
<td>3.04 (5.22)</td>
<td>0.39</td>
<td>11.72 (7.17)</td>
<td>15.15 (7.34)</td>
</tr>
<tr>
<td>ECL</td>
<td>4.02 (4.90)</td>
<td>4.34 (5.81)</td>
<td>0.06</td>
<td>4.73 (5.54)</td>
<td>8.71 (7.13)</td>
</tr>
<tr>
<td>GCL</td>
<td>4.90 (5.79)</td>
<td>9.58 (8.03)</td>
<td>0.67</td>
<td>8.80 (8.42)</td>
<td>12.25 (9.27)</td>
</tr>
</tbody>
</table>

Of interest, Table 4.6 shows high anxiety participants reported higher germane cognitive load than low anxiety participants. One would expect high anxiety participants to invest fewer germane resources as a result of WM being compromised by their anxiety. This effect was significant for tasks of low element interactivity ($F(1,51) = 5.644, p = .021$). All other effects were non-significant.

Pearson’s product correlations were calculated between participants’ baseline maths anxiety and effort ratings from the CLSRS (Paas, 1992) and between participants’ baseline maths anxiety and components of cognitive load (ICL, ECL, GCL) from the CLDS (Leppink et al., 2013) for tasks of low, moderate and high element interactivity. These results are shown in Table 4.7. Table 4.7 shows at both moderate and high levels of element interactivity, significant positive correlations were identified between a participant’s AMAS score and all measures of cognitive load. As a participant’s baseline measure of maths anxiety increased, so too did their subjective measure of mental effort (CLSRS) (Paas, 1992) and their subjective measure of ICL, ECL and GCL (CLDS) (Leppink et al., 2013). This means that participants with high baseline maths anxiety perceived tasks to be more complex, require more effort and demand greater investment of germane resources.
Table 4.7

*Correlation Between Cognitive Load Measures and Participants’ AMAS Score*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Low EI</th>
<th>Moderate EI</th>
<th>High EI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLSRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>( r(68) = .189, p = .123 )</td>
<td>( r(69) = .359, p = .002 )</td>
<td>( r(68) = .337, p = .005 )</td>
</tr>
<tr>
<td>CLDS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICL</td>
<td>( r(69) = .212, p = .080 )</td>
<td>( r(69) = .303, p = .011 )</td>
<td>( r(68) = .262, p = .031 )</td>
</tr>
<tr>
<td>ECL</td>
<td>( r(69) = .074, p = .548 )</td>
<td>( r(69) = .304, p = .011 )</td>
<td>( r(68) = .389, p = .001 )</td>
</tr>
<tr>
<td>GCL</td>
<td>( r(69) = .262, p = .029 )</td>
<td>( r(69) = .386, p = .001 )</td>
<td>( r(68) = .343, p = .004 )</td>
</tr>
</tbody>
</table>

Overall, these results showed that high baseline maths anxiety was strongly, positively correlated with participants’ subjective measures of cognitive load, with all correlations being significant for tasks of moderate and high element interactivity. Thus, Hypothesis 3, that predicted participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety, was supported.

The impact of a participant’s baseline maths anxiety on each of these measures was investigated for both the CLT compliant condition and the CLT non-compliant condition. Additional analysis was conducted using a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) analysis of variance (ANOVA) for participants’ perceived cognitive load measures. This allowed a comparison of cognitive load measures for participants with low baseline maths anxiety and participants with high baseline maths anxiety in both the CLT compliant condition and the CLT non-compliant condition. At high element interactivity, a participant’s baseline measure of baseline maths anxiety (AMAS score) was found to have a significant main effect on a participant’s subjective effort rating \( (F(1,48) = 7.332, p = .009) \). Participants with high baseline anxiety reported higher mental effort ratings (Mean = 6.44, \( SD = 1.54 \)) compared to those with low baseline anxiety (Mean = 5.27, \( SD = 1.54 \)). This represents a large effect size \( (d = 0.8) \). More specifically, the difference in mental effort ratings for participants with high baseline anxiety compared to low baseline anxiety represents a large effect size for CLT compliant condition, \( d = 1.02 \), but only a small effect size for the CLT non-compliant condition, \( d = 0.1 \).
condition, \( d = 0.38 \). This indicates that high anxiety had a greater impact on the total mental effort ratings in the CLT compliant condition, compared to the CLT non-compliant condition.

### 4.4.3 Part 3 - Analysis Incorporating Instructional Conditions And Participant Anxiety

Part 3 of the results addressed Research Questions 3 and 4, as well as the Exploratory Questions 1 and 2, and was based on a participant’s baseline maths anxiety groupings within each condition. This allowed the investigation of how instructional materials designed according to CLT principles may provide support to learners with high maths anxiety.

The analysis undertaken reports findings for participants’ total scores, subjective ratings of cognitive load and subjective ratings of perceived task anxiety. Analysis considered the level of element interactivity and participants’ baseline maths anxiety. Analyses of variables beyond those addressed specifically in the research questions, such as expertise, task completion time and task importance (see Section 4.3.2) are included as additional findings as appropriate with full details of these analyses available in Appendix J.

#### 4.4.3.1 Performance

For Research Question 3, data for participants’ performance scores were analysed based on baseline mathematics anxiety levels, that is, low and high mathematics anxiety categories in each condition. Descriptive results for these four groups are presented in Table 4.8. The results showed that participants with high baseline mathematics anxiety did not achieve higher performance scores when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials compared to participants with high baseline mathematics anxiety using CLT non-compliant instructional materials.
Table 4.8

Descriptive Statistics – Performance with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA $n = 14$</td>
</tr>
<tr>
<td>Low (/10)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low (/10)</td>
<td>9.00 (2.22)</td>
</tr>
<tr>
<td>Moderate (/10)</td>
<td>7.14 (2.14)</td>
</tr>
<tr>
<td>High (/10)</td>
<td>6.93 (2.23)</td>
</tr>
<tr>
<td>Total (/30)</td>
<td>23.07 (5.70)</td>
</tr>
</tbody>
</table>

A one-way ANOVA for performance scores confirmed no significant effects between the four groups at high element interactivity, $F(3,49) = 0.498, p = .686$. There was no significant difference between the performance scores of highly anxious participants in the CLT compliant condition (CCHA) and the CLT non-compliant condition (CNHA): $F(1,22) = 0.008, p = .930$. Thus, Hypothesis 4, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity, was not supported. High anxiety had a negative effect on the performance scores of participants using both CLT compliant and CLT non-compliant materials. CLT compliant instructions did not improve the performance of highly anxious students when completing complex problems.

4.4.3.1.1 Additional Findings for Performance Results

Additional analysis revealed some notable results of high element interactivity performance scores for participants with low baseline mathematics anxiety using CLT compliant materials. This group, the CLT compliant, low anxiety group (CCLA) achieved the highest performance score for tasks of high element interactivity across the four groups (refer to Table 4.8). Analysis using a 2x2x3 ANOVA showed that the CCLA group reported a statistically significant higher performance score compared to all other groups completing problems of high element interactivity.
Calculating the effect size (using Cohen’s $d$) revealed a large effect size in performance across the 4 groups. This is elaborated as follows:

- CCLA significantly outperformed CCHA, $F(1,24) = 10.155, p = .004 (d = .82)$. This result provides evidence that performance was negatively impacted by high baseline mathematics anxiety.

- CCLA significantly outperformed CNLA $F(1,27) = 10.757, p = .003 (d = .72)$. This result indicates that CLT compliant instructional materials supported low baseline mathematics anxiety participants when solving mathematics problems of high element interactivity.

- CCLA significantly outperformed CNHA, $F(1,24) = 8.624, p = .007 (d = .73)$. This result shows that participants with low baseline mathematics anxiety that used CLT compliant instructional materials performed better than participants with high baseline mathematics anxiety that used CLT non-compliant instructional materials.

Collectively, these findings show that high baseline mathematics anxiety had a significant negative impact on performance. Presenting these findings visually (see circled column in Figure 4.7) clearly illustrates the superior performance of the CCLA group compared to all other groups at high element interactivity.

![Figure 4.7](image)

*Figure 4.7. Graph of mean performance scores for experimental groups.*

Findings for the CLT compliant low anxiety group (CCLA) indicated both the design of instructional materials and participants’ baseline maths anxiety affected participants’
performance scores. From these findings it may be hypothesised that participants’ working memory resources were expended due to anxiety, an inferior instructional design (CLT non compliant condition), or both, for the other three experimental groups.

4.4.3.2 Extraneous Cognitive Load

Research Question 4 investigated whether participants with high baseline mathematics anxiety presented with CLT compliant materials experienced lower extraneous cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant materials when solving problems of high element interactivity. Participants’ ratings of cognitive load were measured using two scales following completion of each set of maths problems. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992). Participants’ subjective rating of extraneous cognitive load was measured using items 4-6 from the Cognitive Load Differentiating Scale (CLDS) (Leppink et al., 2013). The results for both subjective cognitive load scales are presented below.

4.4.3.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992)

For Research Question 4, data related to participants’ mental effort ratings were analysed based on participants’ baseline mathematics anxiety. Descriptive results for the four experimental groups are presented in Table 4.9.

Table 4.9

<table>
<thead>
<tr>
<th>Element</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactivity (EI)</td>
<td>CCLA n = 14</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>2.39 (1.19)</td>
<td>3.17 (1.90)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.42 (1.63)</td>
</tr>
<tr>
<td>High</td>
<td>5.12 (1.42)</td>
</tr>
<tr>
<td>Total</td>
<td>10.79 (3.45)</td>
</tr>
</tbody>
</table>
Analysis using a one-way ANOVA revealed that the experimental group, that is, the instructional condition and participants’ baseline maths anxiety, had a significant effect on participants’ total mental effort ratings, $F(3,49) = 3.211, p = .031$. These results show that the CLT compliant high baseline mathematics anxiety group (CCHA) reported lower mean mental effort ratings than the CLT non-compliant high baseline mathematics anxiety group (CNHA) at high element interactivity, however, this difference was not significant, $F(1,22) = 0.345, p = .563$. Conversely, when completing tasks of moderate element interactivity, CCHA reported higher mental effort ratings than CNHA. Therefore, despite this non-significant result, it may be that CLT compliant materials provide some support to highly anxious learners at high levels of element interactivity. The potential benefit of CLT compliant materials for high anxiety participants when solving maths problems of high element interactivity was further investigated.

As shown in Figure 4.8, the CLT non-compliant high anxiety group (CNHA) reported a greater change in mental effort ratings from moderate element interactivity to high element interactivity than the CCHA group. This increase was significant for the CNHA group, $F(1,22)=15.801, p<.001$ (medium effect size: $d = .63$). However, for the CLT compliant high anxiety group (CCHA), the change in mental effort ratings from moderate to high element interactivity was not significant, $F(1,22) = 1.138, p = .298$.
(small effect size: $d = .213$). This suggests that CLT compliant materials may have had a beneficial effect at higher levels of element interactivity for highly anxious students. The results support previous research that an increase in element interactivity creates greater cognitive load (Sweller, 2010), and this additional load may have a greater impact on highly anxious learners.

At high element interactivity, the mental effort experienced by participants with high anxiety using CLT non-compliant instructional materials (CNHA group) increased significantly from that experienced at moderate element interactivity. Additionally, participants with high anxiety using CLT non-compliant materials (CNHA group) surpassed the reported mental effort of highly anxious participants using CLT compliant materials (CCHA group). However, as discussed above, this difference between the two groups at high element interactivity was not significant.

4.4.3.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

For Research Question 4, data related to participants’ extraneous cognitive load ratings were analysed based on participants’ baseline mathematics anxiety. Descriptive statistics for the four experimental groups are presented in Table 4.10.

Table 4.10

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA $n = 14$</td>
</tr>
<tr>
<td></td>
<td>Mean ($SD$)</td>
</tr>
<tr>
<td>Low</td>
<td>4.57 (5.76)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.79 (3.82)</td>
</tr>
<tr>
<td>High</td>
<td>4.93 (5.11)</td>
</tr>
<tr>
<td>Total</td>
<td>13.29 (11.67)</td>
</tr>
<tr>
<td></td>
<td>CCHA $n = 12$</td>
</tr>
<tr>
<td></td>
<td>Mean ($SD$)</td>
</tr>
<tr>
<td>Low</td>
<td>3.42 (4.42)</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.67 (5.69)</td>
</tr>
<tr>
<td>High</td>
<td>11.42 (7.19)</td>
</tr>
<tr>
<td>Total</td>
<td>21.50 (13.55)</td>
</tr>
<tr>
<td></td>
<td>CNLA $n = 15$</td>
</tr>
<tr>
<td></td>
<td>Mean ($SD$)</td>
</tr>
<tr>
<td>Low</td>
<td>3.47 (4.03)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.00 (3.70)</td>
</tr>
<tr>
<td>High</td>
<td>4.53 (5.97)</td>
</tr>
<tr>
<td>Total</td>
<td>11.00 (12.71)</td>
</tr>
<tr>
<td></td>
<td>CNHA $n = 12$</td>
</tr>
<tr>
<td></td>
<td>Mean ($SD$)</td>
</tr>
<tr>
<td>Low</td>
<td>5.25 (7.19)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.75 (6.21)</td>
</tr>
<tr>
<td>High</td>
<td>6.00 (7.06)</td>
</tr>
<tr>
<td>Total</td>
<td>15.00 (18.87)</td>
</tr>
</tbody>
</table>

Table 4.10 shows mean ECL ratings for groups incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions for tasks of low, moderate and high element interactivity. Results of the one-way ANOVA showed the experimental group
had no significant effect on ECL ratings at high element interactivity, $F(49,3) = 1.290, p = .288$.

![Extraneous Cognitive Load](image)

**Figure 4.9.** Graph of extraneous cognitive load for experimental groups.

Figure 4.9 shows for the CCHA group, participants reported higher mean ECL ratings at high element interactivity (although not significantly) than at moderate element interactivity, $F(1,20) = 4.166, p = .055$. Furthermore, the CCHA group reported higher mean ECL ratings than the CLT non-compliant high anxiety group (CNHA) at high element interactivity. However, this difference was not significant, $F(1,22) = 3.468, p = .076$.

Results indicated no significant difference for either subjective mental effort ratings or subjective ratings of ECL for highly anxious participants using CLT compliant materials compared to CLT non-compliant materials. Results showed that the CLT compliant materials did not reduce the extraneous cognitive load experienced by highly anxious learners. Thus, Hypothesis 5, participants with high baseline maths anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant instructional materials when solving mathematics problems of high element interactivity, was not supported.
4.4.3.2.3 Additional Findings for Mental Effort and ECL

Additional analysis was conducted for mental effort ratings at low element interactivity, for mental effort ratings for low anxiety participants, as well as the relationship between mental effort and participants’ task completion time, efficiency and participants’ level of expertise.

Importantly, tasks of low element interactivity resulted in corresponding significantly lower mental effort ratings compared with tasks of high element interactivity ($F(1,136) = 225.59, p < .001$). Of interest, for tasks of high element interactivity, participants with low anxiety using CLT compliant materials (CCLA) reported significantly lower mental effort ratings compared with participants with high anxiety, when using CLT compliant materials (CCHA), $F(1,29) = 8.914, p = .006$, and when using CLT non-compliant materials (CNHA), $F(1,21) = 12.935, p = .002$.

Analysis of task completion time showed a significant relationship with participants’ reported mental effort. There was a significant correlation between mental effort and time taken to complete tasks at low ($r = .407, n = 70, p < .001$), moderate ($r = .452, n = 71, p = < .001$) and high ($r = .512, n = 70, p < .001$) element interactivity. Furthermore, task completion time was greater at higher levels of element interactivity ($F(2,156) = 69.523, p < .001$). Descriptive statistics for task completion time can be found in Appendix J (Table J6).

Mental effort ratings ascertained from the CLSRS were used in conjunction with performance scores to calculate instructional efficiency. This allowed analysis of the effectiveness of the materials used at different levels of element interactivity and for participants with low and high baseline maths anxiety. Efficiency scores did not indicate any significant instructional advantage for highly anxious participants using CLT compliant materials. Further details of these additional analyses can be found in Appendix J (Table J4).

Of particular interest were findings related to expertise, given the relationship between expertise and the cognitive load associated with element interactivity (Paas et al., 100
Expertise was determined according to the criteria explained in Section 4.2.2 and 4.2.4. Novices reported significantly higher subjective ratings of cognitive load than experts in all groups. In both the CLT compliant condition and the CLT non-compliant condition, participants with high levels of baseline anxiety experienced significantly higher cognitive load than participants with low baseline anxiety. This supports previous findings that anxiety consumes working memory resources and contributes to the cognitive load of the task (Darke, 1988a; Eysenck, 1998; Eysenck & Calvo, 1992; Shackman et al., 2006). In addition, the CLT non-compliant high anxiety group (CNHA) reported the highest cognitive load overall for both experts and novices. Expertise was shown to have a significant effect on mental effort ratings for participants with high anxiety using CLT non-compliant materials. Further details of these additional analyses can be found in Appendix J (Table J5).

Results showed in both the CLT compliant condition and the CLT non-compliant condition, highly anxious participants reported higher total extraneous cognitive load compared to low anxious participants (see Table 4.10). The difference between the low anxious and highly anxious participants was significant in the CLT compliant condition, $t(24) = 2.682, p = .0125$. The CLT compliant high anxiety group (CCHA) reported the highest total ECL and specifically with problems of moderate and high element interactivity. In this case, the combination of high anxiety and CLT compliant instructions may have contributed to increased participants’ reported extraneous cognitive load when compared to either condition in isolation. That is, participants with either high baseline anxiety but using CLT non-compliant materials (CNHA) or using CLT compliant materials but with low baseline anxiety (CCLA) reported lower extraneous cognitive load compared to participants with high anxiety and using CLT compliant materials (CCHA). High anxiety and the use of CLT compliant materials together contributed to an increase in subjective ECL ratings. However, the interaction was not significant, $F(3,57) = 1.858, p = .147$.

4.4.3.3 Intrinsic and Germane Cognitive Load

For Exploratory Question 1, data for participants’ subjective ratings of intrinsic cognitive load and germane cognitive load were analysed according to participants’
baseline mathematics anxiety and participants’ instructional condition. This was done in order to investigate the impact of high baseline mathematics anxiety on ICL and GCL when presented with CLT compliant instructional materials compared to CLT non-compliant instructional materials when solving maths problems of high element interactivity. These ratings were measured using the CLDS (Leppink et al., 2013).

4.4.3.3.1 Intrinsic Cognitive Load

Descriptive statistics for the subjective ratings of ICL for the four experimental groups are presented in Table 4.11.

Table 4.11
Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 14</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>1.43 (1.99)</td>
</tr>
<tr>
<td>Moderate</td>
<td>5.32 (3.87)</td>
</tr>
<tr>
<td>High</td>
<td>11.50 (5.77)</td>
</tr>
<tr>
<td>Total</td>
<td>18.25 (9.61)</td>
</tr>
</tbody>
</table>

Table 4.11 shows data for ICL incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions at low, moderate and high element interactivity. Results of the one-way ANOVA showed the experimental group had no significant effect on ICL ratings at high element interactivity, $F(3,49) = 1.037, p = .384$. Overall, high baseline maths anxiety resulted in a corresponding increase in reported ICL. ICL ratings were highest in the CLT non-compliant condition, with the CNHA group highest overall. However, there was no significant difference between ICL ratings of the CCHA and CNHA groups, $F(1,22) = 0.237, p = .631$. Thus, highly anxious learners reported similar intrinsic cognitive load ratings (ICL ratings) when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials and CLT non-compliant instructional materials.
4.4.3.3.2 Germane Cognitive Load

Descriptive statistics for the subjective ratings of GCL for the four experimental groups are presented in Table 4.12.

Table 4.12
Descriptive Statistics – Germane Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA ( n = 14 )</td>
</tr>
<tr>
<td>Low</td>
<td>Mean ((SD))</td>
</tr>
<tr>
<td></td>
<td>6.00 (6.11)</td>
</tr>
<tr>
<td>Moderate</td>
<td>7.43 (7.65)</td>
</tr>
<tr>
<td>High</td>
<td>10.86 (8.27)</td>
</tr>
<tr>
<td>Total</td>
<td>24.29 (18.28)</td>
</tr>
</tbody>
</table>

Table 4.12 shows that for both the CLT compliant condition and the CLT non-compliant condition, high anxiety participants reported higher germane cognitive load ratings than low anxiety participants when solving problems at high element interactivity. Results from the one-way ANOVA for GCL ratings indicated a non-significant main effect for GCL between the four experimental groups, \(F(49,3) = 2.438\), \(p = .076\).

Figure 4.10. Graph of germane cognitive load for experimental groups.
Each group reported higher GCL ratings at higher levels of element interactivity. The exception to this was reported GCL of the CLT non-compliant high anxiety group (CNHA). Interestingly, as shown in Figure 4.10, when using CLT compliant materials, highly anxious participants (CCHA group) invested more germane resources when solving a task of high element interactivity compared to a task of moderate element interactivity. Conversely, highly anxious participants using CLT non-compliant materials (CNHA group) did not invest more germane resources when solving a task of high element interactivity compared to when solving a task of moderate element interactivity. The GCL ratings for the CLT non-compliant high anxiety group (CNHA) were lower at high element interactivity compared to moderate element interactivity, and dropped to below the reported GCL of the CLT compliant high anxiety group (CCHA). Highly anxious participants reported significantly higher GCL ratings at high element interactivity than at low element interactivity when using CLT compliant materials, $F(1,44) = 4.202, p = .046$, but did not when using CLT non-compliant materials, $F(1,28) = 0.01, p = .985$. The investment of working memory resources in GCL for those using CLT compliant materials increased according to the greater demands associated with tasks of high element interactivity. Additional analysis showed a significant positive correlation between participants’ ratings of task importance and the investment of germane resources, $r = .295, n = 53, p = .032$. Descriptive statistics relevant to these additional findings related to task importance can be found in Appendix J (Table J1).

For maths tasks of high element interactivity, there was no significant difference in GCL ratings between the CLT compliant high anxiety group (CCHA) and CLT non-compliant high anxiety group (CNHA), $F(1,22) = 0.031, p = .862$. Thus, highly anxious learners reported similar germane cognitive load (GCL ratings) when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials and CLT non-compliant instructional materials.

### 4.4.3.4 Perceived Task Anxiety Ratings

For Exploratory Question 2, data for participants’ perceived task anxiety were analysed according to participants’ baseline mathematics anxiety and participants’ instructional
condition. This was done in order to investigate whether participants with high baseline mathematics anxiety presented with CLT compliant instructional materials reported lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials when solving maths problems of high element interactivity. Descriptive statistics for the perceived task anxiety ratings of the four experimental groups are presented in Table 4.13.

Table 4.13

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 14</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>1.79 (0.70)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.57 (1.45)</td>
</tr>
<tr>
<td>High</td>
<td>3.18 (1.20)</td>
</tr>
<tr>
<td>Total</td>
<td>7.54 (2.29)</td>
</tr>
</tbody>
</table>

Table 4.13 shows perceived task anxiety was higher at higher levels of element interactivity for all groups. This result confirmed that higher levels of task complexity (higher element interactivity) resulted in higher perceived task anxiety ratings. The experimental group, comprising variables of instructional condition and baseline maths anxiety, had a significant effect on the overall perceived task anxiety rating, $F(3, 49) = 5.733$, $p = .002$, confirming a relationship between baseline maths anxiety, CLT compliant instructional materials and perceived task anxiety at high element interactivity. The CLT non-compliant low anxiety group (CNLA) had the lowest perceived task anxiety at all levels of element interactivity, compared to all other groups.
As shown in Figure 4.11, perceived task anxiety was higher for participants with high levels of baseline anxiety than those with low baseline anxiety levels at all levels of element interactivity for both the CLT compliant condition and the CLT non-compliant condition. At high element interactivity, this difference was significant for the CLT compliant condition, $F(1,24) = 13.067$, $p = .001$ and for the CLT non-compliant condition, $F(1,25) = 5.154$, $p = .032$. Figure 4.11 shows the CLT non-compliant high anxiety group (CNHA) reported a greater increase in perceived task anxiety when completing maths problems of moderate element interactivity and high element interactivity compared to the increase in perceived task anxiety for the CLT compliant high anxiety group (CCHA). This increase was not significant for the CLT non-compliant high anxiety group (CNHA), $F(1,22) = 4.134$, $p = .054$ (large effect size: $d = 0.83$) or for the CLT compliant high anxiety group (CCHA), $F(1,22) = 1.609$, $p = .218$ (medium effect size: $d = 0.52$). Thus, there was no significant difference in perceived task anxiety ratings between these groups when solving problems of high element interactivity, $F(1,22) = 0.257$, $p = .617$.

The perceived task anxiety of high anxiety participants was not alleviated by the learning support associated with the use of CLT compliant instructional materials. At high element interactivity, there was no significant difference in the level of perceived task anxiety experienced by the CLT compliant high anxiety group (CCHA) and the
CLT non-compliant high anxiety group (CNHA). These results suggest that CLT compliant instructional materials have not supported highly anxious learners by reducing the anxiety associated with a complex mathematics task.

4.4.3.4.1 Additional Findings - Perceived task Anxiety and Expertise

The level of element interactivity relevant to a task is dependent on a learner’s domain specific expertise (Paas et al., 2003b). Furthermore, tasks of high element interactivity are more likely to adversely effect learners as a result of anxiety (Hunt, 2011). These findings for perceived task anxiety (Section 4.4.3.4) indicated that complex tasks incurred greater perceived task anxiety ratings than simple tasks. Results from a one-way ANOVA indicated the difference in perceived task anxiety ratings at low element interactivity and high element interactivity was significant for highly anxious participants in both the CLT compliant condition, \( F(1,22) = 15.014, p < .001 \), and the CLT non-compliant condition, \( F(1,22) = 14.143, p = .001 \). It was therefore considered worthwhile to further investigate the relationship between expertise and perceived task anxiety. A one-way ANOVA was conducted to investigate additional findings regarding the effect of expertise on participants’ reported perceived task anxiety ratings. Results indicated expertise had a significant effect on perceived task anxiety at moderate element interactivity, \( F(67,1) = 19.042, p < .001 \) and at high element interactivity, \( F(66,1) = 23.877, p < .001 \) (Result was not significant at low element interactivity, \( F(67,1) = 1.828, p = .181 \)).

4.5 DISCUSSION

The overall purpose of this experiment was to investigate whether CLT compliant instructional materials, that is, paired process-oriented worked examples presented with no split attention effects, could support learners with high mathematics anxiety in a secondary school context to solve complex algebra problems. The experiment involved participants with low or high baseline maths anxiety solving maths tasks of low, moderate and high element interactivity using either CLT compliant materials or CLT non-compliant materials. Previous research has confirmed that (i) an increase in element
interactivity adversely effects performance and increases the cognitive load associated with those tasks (Paas & van Merriënboer, 1993), (ii) CLT compliant instructional materials improve performance on tasks and reduce the cognitive load associated with those tasks (Paas et al., 2003b) and (iii) instructional materials designed according to CLT support learning when solving maths problems of high element interactivity (Sweller et al., 1998). Previous research has also established the level of element interactivity associated with a task is dependent on a learners domain specific expertise (Kalyuga, 2007).

The main emphasis for this experiment was fourfold. Firstly, it was necessary to confirm previous research that has shown that learners perform better and report lower cognitive load for tasks of high element interactivity when presented with instructional materials designed in accordance with the principles of cognitive load theory (CLT) than when presented with instructional materials not designed in accordance with CLT principles. Secondly, it was imperative to investigate the relationship between learner anxiety and cognitive load and establish the nature of the association between these two measures. The experiment then examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element interactivity by improving performance scores and reducing cognitive load. Finally, Experiment 1 examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element interactivity by reducing perceived task anxiety when solving high element interactivity maths problems.

Four research questions and two exploratory questions guided this investigation to examine whether CLT compliant materials would support highly anxious learners and thus result in improved performance and lower extraneous cognitive load. This section will address each research question and the main findings will be discussed in the context of other research.
4.5.1 Performance and Cognitive Load across Instructional Conditions

The first research question was: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

Firstly, it was expected that when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 1). Performance scores were significantly lower for tasks of high element interactivity compared to tasks of low element interactivity, consistent with previous research findings (Sweller, 1994). However, the findings showed that there was no significant difference in the performance scores of participants provided with CLT compliant instructional materials compared to participants provided with CLT non-compliant materials (refer to section 4.4.1.1). Thus, hypothesis 1 was not supported.

Secondly, it was expected when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 2). Participants reported significantly higher cognitive load ratings for tasks of high element interactivity compared to tasks of low element interactivity. However, the findings show that there was no significant difference in the cognitive load ratings of participants provided with CLT compliant materials compared to participants provided with CLT non-compliant materials (refer to section 4.4.1.2). These findings were consistent for both mental effort ratings (Paas, 1992) and extraneous cognitive load ratings (Leppink et al., 2013). Thus, hypothesis 2 was not supported.
4.5.2 Cognitive Load and Baseline Mathematics Anxiety

Research Question 2 was: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?

It was predicted that participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher load imposed on working memory caused by anxiety (Hypothesis 3). At high element interactivity, there was a significant positive correlation between participants’ baseline maths anxiety and all subjective ratings of cognitive load: mental effort using the CLSRS (Paas, 1992), and ICL, ECL and GCL using the CLDS (Leppink et al., 2013) (refer to Table 4.7). These results confirmed Hypothesis 3 and thus established a relationship between anxiety and cognitive load.

Anxiety places a burden on working memory (Eysenck & Payne, 2006) and is therefore an important factor in CLT research. High levels of baseline maths anxiety increased the cognitive load associated with a task when using both CLT compliant instructional materials and CLT non-compliant instructional materials. However, high baseline maths anxiety had a large effect on participants’ mental effort ratings when using CLT compliant materials, and only a small effect when using CLT non-compliant materials (refer to Section 4.4.2). There are two possible explanations that can be considered to account for this result. Firstly, the comprehensive materials provided in the CLT compliant condition could have been overwhelming for participants with high baseline maths anxiety. In association with anxious thoughts dominating their working memory whilst completing a task, in contrast to expectations according to CLT, highly anxious participants may have overlooked the benefits of the worked examples and perceived the task to be more demanding compared to highly anxious participants with CLT non-compliant materials. A second possibility was that the greater mental effort associated with CLT compliant materials compared to CLT non-compliant materials for highly anxious participants could be a consequence of the significantly higher GCL reported (indicative of greater understanding) when using CLT compliant materials (refer to section 4.4.1.4). CLT compliant instructional materials encouraged additional understanding of the task and therefore supported learning for highly anxious learners.
4.5.3 Problem solving Performance

The third research question was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) would outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) on performance scores, due to the reduction of extraneous cognitive load and greater investment of germane resources afforded by CLT compliant instructional materials (Hypothesis 4). These findings showed that highly anxious learners did not achieve significantly higher performance scores while using CLT compliant instructional materials compared to highly anxious learners using CLT non-compliant instructional materials when solving complex (high element interactivity) mathematics problems (refer to Table 4.8). Thus Hypothesis 4 was not supported. High anxiety had a negative effect on the performance scores of participants using both CLT compliant and CLT non-compliant materials. CLT compliant instructions did not improve the performance of highly anxious learners when completing complex problems.

Whilst Hypothesis 4 was not confirmed, the CLT compliant condition resulted in higher mean performance scores than the CLT non-compliant instructional condition at high element interactivity (refer to Table 4.3). This difference was close to significant and may infer that cognitive resources being consumed by anxiety and task complexity affected performance. Therefore, at high element interactivity, CLT compliant materials provided support for highly anxious learners. However, the beneficial effect of CLT compliant materials may have been masked by the significantly higher baseline anxiety of participants in the CLT compliant condition compared to the CLT non-compliant condition (refer to Section 4.3.1 and Table 4.2). Any learning support associated with the use CLT compliant instructional materials could have been negated by the working
memory consumed by learners’ high anxiety. Therefore, although not significant, performance may have been negatively impacted by a combination of high maths anxiety and the use of CLT non-compliant materials.

Interestingly, for tasks of high element interactivity, the CLT compliant low anxiety group (CCLA group) achieved significantly higher performance scores than the other 3 groups (refer to section 4.4.3.1.1). This indicated both the design of instructional materials and participants’ baseline maths anxiety affected participants’ performance scores. For participants with low maths anxiety, CLT compliant materials supported learning. This suggests that participants’ working memory resources have been consumed due to anxiety, inferior instructional design, or a combination of both, for the other three experimental groups.

### 4.5.4 Extraneous Cognitive Load

Cognitive load was measured using scales based on the Cognitive Load Subjective Rating Scale (Paas, 1992) for mental effort ratings, and the recently developed instrument for measuring different types of cognitive load (Leppink et al., 2013) for ratings of extraneous cognitive load. Results for cognitive load ratings have been presented and explained based on both of these scales. Research question 4 was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials would report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials (Hypothesis 5).
Overall, an increase in element interactivity generated a corresponding increase in mental effort ratings for all groups (refer to Table 4.9), which was expected given the increased complexity of the task. For highly anxious participants using CLT compliant instructional material (CCHA group), the reported mental effort ratings were significantly higher than for highly anxious participants using CLT non-compliant instructional material (CNHA group) when comparing tasks of low element interactivity and moderate element interactivity. However, at high element interactivity, the mental effort experienced by participants with high anxiety using CLT non-compliant instructional materials (CNHA group) was greater than the reported mental effort of highly anxious participants using CLT compliant materials (CCHA group). At high element interactivity, the difference in mental effort ratings was not significant. Despite the mental effort ratings of the CCHA group not being significantly lower than the CNHA group at high element interactivity, this result suggests that CLT compliant materials may have supported highly anxious learners at high levels of element interactivity (refer to Figure 4.8).

Furthermore, an increase in the level of element interactivity resulted in a concomitant increase in ECL (refer to Table 4.10). For tasks of high element interactivity, there was no significant difference in ECL ratings between the CLT compliant and CLT non-compliant conditions (refer to Section 4.4.3.2.2). Thus, this extraneous load was not alleviated by the use of CLT compliant instructional materials. For tasks of high element interactivity, highly anxious participants using CLT compliant materials reported higher ECL compared to highly anxious participants using CLT non-compliant materials, although this was not significant. The combination of high anxiety and CLT compliant instructions significantly increased a participant’s reported extraneous cognitive load when compared to either condition in isolation (refer to Section 4.4.3.2.2). That is, participants with either high baseline anxiety but using CLT non-compliant materials (CNHA) or using CLT compliant materials but with low baseline anxiety (CCLA) reported significantly lower extraneous cognitive load than participants with high anxiety and using CLT compliant materials (CCHA).

These findings indicate there were no significant differences for subjective mental effort ratings or subjective ratings of ECL of highly anxious learners when using CLT
compliant materials compared to CLT non-compliant materials. Thus, Hypothesis 5 was not supported. This does not support previous research that suggests the use of worked examples reduces the ECL of a task (Paas et al., 2003b). This could be attributed to participants not requiring the assistance provided by worked examples due to their expertise or to participants not using worked examples effectively. In addition, participants in the CLT compliant condition had significantly higher baseline maths anxiety. Therefore, the learning support provided by CLT compliant materials when solving complex tasks may have been compromised by high anxiety. Furthermore, anxious learners may have been overwhelmed by the additional instructional materials, inclusive of worked examples, and consequently experienced a greater load.

Despite Hypothesis 5 not being confirmed, the following interesting results surfaced when findings related to low anxious participants, completion time and expertise were investigated (refer to Section 4.4.3.2.3).

Firstly, at high element interactivity, the highest mental effort ratings overall were reported by the CLT non-compliant high anxiety (CNHA) group. Conversely, the lowest effort overall was experienced by the CLT compliant low anxiety (CCLA) group. Collectively, CLT compliant materials and low baseline levels of maths anxiety significantly reduced cognitive load, poorly designed instructional materials or anxiety respectively, have not consumed limited cognitive resources.

Secondly, the time taken to complete a task increased for all groups as element interactivity increased. The use of CLT compliant materials and high baseline anxiety increased the time taken to complete problems at all levels of element interactivity. The CCHA group had greatest completion time at all levels of element interactivity which could be attributed to the time taken by participants to inspect the relevant worked examples provided, suggesting participants made use of worked examples while solving problems. Overall, the increased effort and time associated with tasks of high element interactivity for highly anxious participants did not translate into significantly greater performance scores for the maths tasks completed (refer to results in Section 4.4.3.2.3).
Finally, higher mental effort ratings of those participants using CLT compliant materials may have been as a result of the level of expertise of the participants. For participants already competent in the mathematics domain of algebra, the provision of worked examples may in fact have added to the extraneous cognitive load of a task. The Expertise Reversal effect suggests the use of worked examples is beneficial only in the early stages of learning and less effective, and potentially detrimental, at later stages of learning (Kalyuga, 2007). This effect is the result of cognitive resources being allocated to additional instructional materials not required by the learner to perform the task successfully. The content used in this research had been previously taught to participants. This eliminated limitations of previous associated research that used novel material that may have been overwhelming for learners, particularly novices, in terms of cognitive load (Kirschner et al., 2006). High baseline maths anxiety led to increased effort ratings at high element interactivity for both experts and novices in both conditions, when participants used both CLT compliant and CLT non-compliant materials. The mental effort ratings of highly anxious participants were significantly higher for novices compared to experts when using CLT non-compliant materials. The expertise of the learner may have compensated for the absence of CLT compliant materials, which led to lower mental effort ratings despite higher anxiety.

High baseline anxiety did not significantly affect the mental effort ratings of experts using CLT compliant materials. However, CLT non-compliant materials created significantly higher mental effort ratings in experts with high anxiety compared to those with low anxiety. This suggests that without the support of CLT compliant instructional materials, participants with high baseline anxiety and expertise experienced greater load when completing complex tasks. Novices consistently reported higher levels of cognitive load when using CLT non-compliant instructions. The greatest subjective ratings of mental effort overall for both novices and experts was in the CNHA group. Descriptive statistics and analysis relevant to these additional findings related to mental effort and expertise can be found in Appendix J (Table J5).
4.5.5 Intrinsic and Germane Cognitive Load

Exploratory question 1 was: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials? Measurement of the individual components of cognitive load using the CLDS (Leppink et al., 2013) allowed an investigation into any effects anxiety may have on ICL and GCL when solving complex tasks. This was an exploratory investigation as the absence of previous relevant research investigating the relationship between intrinsic cognitive load and anxiety, and between germane cognitive load and anxiety, impeded the formulation of a hypothesis.

Intrinsic Cognitive Load

This research investigated whether high anxiety impacted a participant’s subjective rating of ICL, and also whether this differed with the use of CLT compliant materials compared to CLT non-compliant materials. As expected, there was no significant difference between the ICL ratings of participants using CLT compliant materials and CLT non-compliant materials. The intrinsic cognitive load refers to the load associated with the complexity of the task and is independent of instructional design (Sweller, 2010). For all experimental groups, subjective ratings of ICL were higher at higher levels of element interactivity (Sweller, 1994). This indicated the tasks were appropriately categorized as low, moderate and high element interactivity, with high ICL ratings corresponding to high levels of element interactivity. High baseline maths anxiety resulted in increased ICL ratings for participants in both instructional conditions. The highest ICL ratings at all levels of element interactivity and overall were for the CNHA group. However, the difference in ICL ratings between the CCHA group and CNHA group was not significant (refer to Section 4.4.3.3.1). Thus, these findings suggest anxiety does impact the perceived ICL of a complex task for highly anxious learners. However, they do not suggest a difference in ICL exists between high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials when solving problems of high element interactivity.
Germane Cognitive Load

This research investigated whether high anxiety impacted a participant’s subjective rating of GCL, and also if this differed with the use of CLT compliant materials compared to CLT non-compliant materials. Germane cognitive load is the load relevant to learning and refers to the allocation of germane resources to a task (Paas, et al., 2003b). These findings show the reported subjective ratings of GCL were significantly higher with CLT compliant instructional materials when solving maths problems of high element interactivity and overall (refer to Section 4.4.1.4). An increase in the element interactivity resulted in a corresponding increase in GCL ratings for all experimental groups; there was a greater investment of cognitive resources into the task as they became more complex when using CLT compliant materials (refer to Table 4.12). Highly anxious learners reported higher GCL ratings than low anxious learners when solving complex tasks. However, this did not translate to improved performance scores for these participants, although improved understanding may have contributed to their performance scores not being significantly less than low anxious participants (See Section 4.4.3.1.1). Furthermore, highly anxious learners continued to invest germane cognitive resources at high element interactivity only when using CLT compliant materials, whereas highly anxious learners using CLT non-compliant materials did not. Under conditions of high element interactivity, the CNHA group reported a significant decline in the investment of germane resources compared to GCL ratings at moderate element interactivity (refer to Figure 4.9).

The use of CLT compliant materials increased the investment of germane resources. The provision of worked examples may have indicated to participants the escalating complexity of a task and therefore the necessity to invest more cognitive resources to completion of the task. Interestingly, CNHA was the only group to have reported a reduction in GCL ratings at high element interactivity. These participants may have been unable to accommodate additional germane load as a result of the WM demands associated with task complexity, inferior instructional materials and anxiety, all of which consumed limited working memory resources. However, these findings did not indicate a significant difference in GCL between high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with
CLT non-compliant instructional materials when solving problems of high element interactivity.

In addition, there was a significant positive correlation between participants’ ratings of GCL and task importance. Furthermore, participants that used CLT compliant materials considered the task more important than those that used CLT non-compliant materials. This suggests a critical relationship between CLT compliant materials, investment of germane resources and task importance. Therefore, the use of CLT compliant materials may have supported learners by assisting them to recognize the need to appropriately allocate resources to a complex task, and also allowing the working memory capacity to successfully accommodate a complex task. (refer to Section 4.4.3.3.2).

4.5.6 Perceived Task Anxiety Ratings

Exploratory question 2 was: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials? This was investigated as an exploratory question as there was no previous CLT research to allow determination of a hypothesis related to the effect of using CLT compliant materials on task anxiety.

This research examined whether participants with high maths anxiety that used CLT compliant instructional materials (CCHA group) reported lower perceived task anxiety than participants with high maths anxiety that used CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity. The CLT compliant, high anxious group (CCHA) did not experience lower anxiety levels than the non CLT compliant, high anxiety group (CNHA). There was no significant difference in the level of perceived task anxiety experienced by these two groups. These findings showed an increase in task complexity (element interactivity) increased participants’ level of anxiety associated with the task (refer to Table 4.13). Previous research suggests high anxiety is more likely to be detrimental to learning when completing complex tasks (Hunt, 2011). Higher levels of element interactivity resulted in
corresponding higher perceived task anxiety ratings when using both CLT compliant and CLT non-compliant materials. Perceived task anxiety was greatest for those with high baseline maths anxiety. This anxiety was not alleviated by the learning support associated with the use of CLT compliant instructional materials.

The CNLA group had the lowest perceived task anxiety at all levels of element interactivity. This may have been a result of the significantly lower baseline anxiety levels measured using AMAS of the CLT non-compliant group overall, despite random allocation of participants into groups. Furthermore, the inclusion of additional instructional materials (paired process-oriented worked examples for each problem to be solved) for participants in the CLT compliant condition may have been overwhelming for those already anxious about the task.

Some interesting findings emerged for the reported perceived task anxiety for highly anxious participants when completing tasks of high element interactivity. At moderate element interactivity, perceived task anxiety was significantly higher for the CCHA group compared to CNHA group. However, perceived task anxiety was not significantly higher for CCHA group compared to CNHA group at high element interactivity. As element interactivity increased from moderate to high, the increase in perceived task anxiety was greater for highly anxious participants using CLT non-compliant materials (CNHA group) compared to highly anxious participants using CLT compliant materials (CCHA group). When solving tasks of high element interactivity, the use of CLT compliant materials may have provided some support for highly anxious participants, and the use of CLT non-compliant materials may have intensified the perceived task anxiety experienced by highly anxious participants. Furthermore, these findings showed expertise significantly reduced participants’ ratings of perceived task anxiety for tasks of high element interactivity. This suggests development of expertise in the domain of mathematics for highly anxious learners may be an important means of alleviating the anxiety associated with a complex mathematics task.
4.5.7 Summary of Results

Overall, of the four research questions investigated, only one of the five associated hypotheses was confirmed. Support of hypothesis 3 indicated an association exists between learner anxiety and cognitive load experienced whilst completing tasks of high element interactivity.

Results showed that both high element interactivity and high learner anxiety had a negative impact on performance, all measures of cognitive load and perceived task anxiety ratings. This experiment found that CLT compliant instructional materials improved performance scores at high element interactivity for low anxiety learners only. At high element interactivity, the CCLA group recorded the highest performance score. Similarly, at high element interactivity, the CCLA group reported the lowest mental effort. However, at high element interactivity, high anxiety learners reported lower mental effort ratings when using CLT compliant materials (CCHA) compared to those using CLT non-compliant instructional materials (CNHA). This difference was not significant. When using CLT non-compliant instructional materials, mental effort ratings were significantly greater at high element interactivity compared to moderate element interactivity. The use of CLT compliant instructional materials reduced ICL (not significantly), increased ECL (significantly) and increased GCL (not significantly) compared to the use of CLT non-compliant instructional materials for high anxiety learners. Importantly, the investment of germane resources was maintained at high element interactivity to levels similar to those at moderate element interactivity when using CLT compliant instructional materials. Conversely, when using CLT non-compliant instructional materials, GCL ratings were significantly lower at high element interactivity compared to moderate element interactivity.

Expertise alleviated the mental effort associated with a task for high anxiety learners. In addition, when experts were using CLT compliant instructional materials, the mental effort ratings for high anxious learners were no different to the mental effort ratings of low anxious learners. The CLT compliant instructional materials effectively nullified the impact of high anxiety for experts.
The use of CLT compliant instructional materials did not significantly reduce perceived task anxiety ratings for high anxiety learners. However, at high element interactivity, the increase in perceived task anxiety was greater for the CNHA compared to the CCHA group. The significant difference in perceived task anxiety ratings at moderate element interactivity was not maintained at high element interactivity. This suggests the use of CLT compliant materials became important for highly anxious learners when solving problems of high element interactivity.

4.6 LIMITATIONS

The main limitation of this study was associated with the categorising of participants into low and high anxiety groups based on their AMAS score. The sample size was relatively small given participants were to be divided into four experimental groups. Sample size for each group in the current study was between 12 and 15, and a total of 53. Cohen (1992) suggests for ANOVA tests, the necessary sample size per group is 45 cases (a total of 180) for a 4-group design with and alpha of .05 and a medium effect size (p. 158). Furthermore, despite random allocation to each condition, participants in the CLT compliant condition attained significantly higher AMAS scores. That is, by chance there were more highly anxious participants in the CLT compliant condition. The higher anxiety experienced by participants in the CLT compliant condition may not only have added to their perceived task anxiety but also to the overall level of cognitive load experienced by these participants when completing mathematics problems of all levels of element interactivity. Any benefit that may have been available to highly anxious learners with the use of CLT compliant instructional materials could have been counteracted by the higher baseline anxiety of participants in this condition. Further investigation of these hypotheses is required with homogeneous groups with regards to anxiety in each condition. Future research should ensure stratified distribution of participants to each group based on the baseline anxiety scores determined in advance of testing, or by utilising a larger sample size. This would ensure potential problems associated with this inherent bias were avoided, and also accurately determine whether CLT compliant instructional materials were able to reduce perceived task anxiety and cognitive load for highly anxious learners. In addition, participants could be asked to elaborate on their anxiety – source of anxiety, reasons for anxiety etc., rather than just
rate their anxiety level to provide greater insight into anxiety factor. Furthermore, there was variation in the actual cut-off scores for low anxiety participants and high anxiety participants in the CLT condition compared to the CLT non-compliant condition. Although participants in both conditions were divided into terciles, higher AMAS cut-off scores for participants in the CLT compliant condition meant the baseline maths anxiety for this condition was higher.

In addition, the usefulness of worked examples can be affected by a learner’s expertise and benefits associated with their use may be impacted by the effectiveness of a learner’s inclusion of them in the problem solving process. The level of element interactivity of a task is dependent on a learner’s prior knowledge. Novices may perceive a relatively simple task as complex, which would result in a greater cognitive load associated with the task and support from worked examples would be of benefit. Experts, however, would not require the support of worked examples for a similar task they find undemanding. Further investigation of the impact of expertise on learner anxiety in future research would be worthwhile.

Further, there was no data collected to serve as evidence that participants actually studied and made use of the worked examples under the CLT compliant conditions. However, the use of worked examples in mathematics instruction is common and it was therefore reasonable to assume that they would have been an integral part of participants’ previous instruction in mathematics. Participants would therefore be familiar with this method of instruction. Results for task completion times do suggest participants in the CLT compliant condition did make use of the worked examples. However, participants were not given direct training on the correct and efficient use of worked examples in instruction as part of this study. If participants had not been sufficiently trained in the use of worked examples, their provision may have required additional processing, therefore creating greater load and potentially adding to the anxiety associated with the task.
4.7 CONCLUSION

These results show that a high level of element interactivity reduced performance scores, increased all measures of cognitive load and increased a participant’s perceived task anxiety rating. It is essential, therefore, that when learners solve complex tasks, strategies are implemented to simplify these problems. This is especially true for learners with high maths anxiety, whose performance, and experience of cognitive load and perceived task anxiety was exacerbated by their maths anxiety. This experiment found that CLT compliant instructional materials might provide some relief for these learners in certain circumstances. However, the over-representation of highly anxious learners in the CLT compliant condition may have impacted the significance of results in a number of circumstances. It emerged that a combination of low anxiety and CLT compliant instructional materials (CCLA group) comprised the most favourable conditions for effective learning, that is, highest performance scores with lowest mental effort ratings.

Experiment 1 was conducted using participants currently engaged in secondary education. High maths anxiety was identified as having a significant negative impact on student performance, cognitive load and task-related anxiety. It has been thought the anxiety levels of teachers may influence the anxiety experienced by students in maths learning environments. Therefore, in order to complement the findings of Experiment 1, Experiment 2 involved participants currently engaged in tertiary education associated with maths teaching. The methodology from Experiment 1 was retained, however, a much larger sample size was sought in order to address limitations associated with the distribution of low and high anxiety participants in this experiment.
5 EXPERIMENT 2

5.1 INTRODUCTION

The overall aim of Experiment 2 was the same as Experiment 1, that is, to determine whether the use of worked examples would support learning of anxious students and reduce anxiety experienced by highly anxious learners when solving maths problems. Experiment 1 was conducted with high school students whilst Experiment 2 was conducted with participants in a tertiary education context. In Experiment 2, participants were pre-service mathematics teachers currently enrolled in tertiary education and analysis of data from these students may contribute to findings in recent research related to teacher anxiety and its effect on students’ maths anxiety.

As for Experiment 1, this experiment was conducted to determine whether worked examples that were designed in compliance with CLT would reduce the load on working memory and lead to a reduction in the anxiety experienced by highly anxious learners. Although Experiment 2 was conducted in a tertiary setting, rather than a secondary education context as in Experiment 1, the focus of the experiment was again fourfold. Firstly, to confirm previous research that has shown the provision of instructional materials designed in accordance with cognitive load theory (CLT) assist learners by reducing cognitive load and improving performance scores when completing complex tasks (see Research Question 1). Findings from Experiment 1 did not confirm these findings and this might have affected the significance of other results in Experiment 1. Secondly, to investigate the relationship between learner anxiety and cognitive load (see Research Question 2). Findings from Experiment 1 provided evidence of a relationship between learner anxiety and cognitive load and it was anticipated Experiment 2 would provide further support for this. Thirdly, this experiment proposed to examine whether worked examples provided assistance to highly anxious learners by reducing learners cognitive load and thereby improving maths performance scores for tasks of high element interactivity (see Research Questions 3 and 4 and Exploratory Question 1). Finally, this experiment investigated whether worked examples assist learners with high maths anxiety when solving maths
problems of high element interactivity by reducing perceived task anxiety (see Exploratory Question 2).

Experiment 2 aimed to achieve two additional purposes to address limitations identified in Experiment 1. Firstly, the sample size in Experiment 1 was small. This experiment engaged a much larger sample. Secondly, in Experiment 1, the mean baseline maths anxiety of the CLT compliant condition was significantly higher than the CLT non-compliant condition. Experiment 2 attained more homogeneous experimental groups in terms of high and low anxiety ratings, in order to ensure even distribution of low and high anxious learners in each experimental condition.

The research questions and associated alternative hypotheses investigated were the same as for Experiment 1 (see Section 4.1). The Exploratory Research Questions being investigated were the same as for Experiment 1 (see Section 4.1).

The following Sections 5.2 and 5.3 provide detail of Methodology and Data Analysis for Experiment 2. The overall methodology was similar to that of Experiment 1. Specific differences implemented in Experiment 2 related to participant groups, instructional materials, experimental materials and the composition of high and low anxiety groups are explained in relevant sections (5.2.2, 5.2.3, 5.2.4 and 5.3.1 respectively).

5.2 METHODOLOGY

5.2.1 Research Design

The research design for Experiment 2 was the same as for Experiment 1. This experiment used a between subjects design to examine performance, cognitive load and perceived task anxiety of tertiary education students when solving a series of fifteen algebra mathematics problems of varying levels of element interactivity (5 of low, 5 of moderate and 5 of high element interactivity). A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial between groups experimental design was implemented.
The independent variables were as follows:

1. Instructional Design Condition: Instructional materials were either CLT compliant or CLT non-compliant (explained below)
2. Baseline maths anxiety: Participants were identified as high mathematics anxiety or low mathematics anxiety based on the Abbreviated Maths Anxiety Scale (see Section 5.3.1)

Instructional materials in the CLT compliant condition were presented as paired process-oriented worked examples. Each mathematics problem to be solved was preceded by a worked example similar to the one to be solved, with key processes highlighted and explained (see Figure 5.1). As for Experiment 1, the worked examples and accompanying problems to be solved were presented in order of increasing complexity, that is, from low element interactivity to high element interactivity. The CLT non-compliant instructional materials were presented as conventional problems to solve, with product-oriented worked examples provided on a separate sheet (see Figure 5.2). The problems to be solved were presented in order of increasing complexity, however, the worked examples provided were not. The evident split attention and presentation of worked examples not ordered according to increasing element interactivity constituted ‘CLT non-compliance’, as for Experiment 1. The instructional materials are explained in more detail in Sections 5.2.3 and 5.2.4.

The dependent variables were as follows:

1. Performance on mathematics tasks;
2. Cognitive load / mental effort measured subjectively using two scales:
   (i) Cognitive Load Subjective rating Scale (CLSRS) (Paas, 1992);
   (ii) Cognitive Load Differentiating Scale (CLDS) differentiating between intrinsic (ICL), extraneous (ECL) and germane (GCL) cognitive load (Leppink et al., 2013);
3. Subjective measure of perceived task anxiety (Baloglu & Zelhardt, 2007);
4. Completion time for algebra tasks in each Section, A, B and C;
5. Perceived task difficulty, task importance, task engagement and task satisfaction. Participants reported subjective ratings of the factors following completion of algebra tasks in each Section, A, B and C. These variables are the same as those in Experiment 1; further detail is presented in Section 4.2.1.

5.2.2 Participants

Two hundred and fifty-two students (63 males and 189 females) enrolled in a first year teacher education course at a New South Wales University participated in the study. Participants in this study were studying maths education and were all aged between 18 and 25 years old. The maths background of these participants varied. No independent testing of participants’ mathematical ability was conducted; however, all participants provided information regarding previous maths experience according to NSW syllabus outcomes (or equivalent). Participants identified the highest level of maths completed in secondary school. Responses ranged from Year 10 maths (Standard, Intermediate, Advanced) to Year 12 maths (general, advanced – 2 unit, extension 1 – 3 unit). This criterion was used to divide students into groups of “experts” or “novices” for additional data analysis found in Section 5.4.3.4.1. Experts were those participants that had completed Year 12 Advanced or Extension Mathematics; Novices had completed only Year 10 or Year 11 Mathematics, or Year 12 General Mathematics.

The experiment was conducted in one two-hour session during Week 2 of Semester One in allocated course lecture time. This allowed sufficient time for instructions to be given to participants and completion of the instructional booklets by all participants. Ethics approval for the experiment was received from the University of Wollongong Human Research Ethics Committee (See Appendix A). Prior to conducting the experiment, email exchanges and one face-to-face meeting took place with relevant staff, consisting of the students’ lecturer and the course convenor. The email exchange confirmed the suitability of students to participate in the study and also that the algebra content was of a suitable standard for participants. The problems to be solved were a Stage 5 standard as for Experiment 1, however, the level of difficulty was adjusted to accommodate the broad range of ability of participants and align effectively with assumed knowledge for
the course. This was done by reducing the number of solution steps required at each level of element interactivity. The face-to-face meeting provided an opportunity to discuss the aims of the research, the relevance of the study and specific instructions for conducting the experiment. Consent and Participant information sheets were provided for distribution to participants (See Appendices N and O).

5.2.3 Instructional Materials

As for Experiment 1, the instructional materials were designed as either CLT compliant or CLT non-compliant. Although the problems to be solved were less difficult than for Experiment 1, the two instructional design conditions were the same as for Experiment 1 and are explained in detail as follows.

CLT Compliant Condition
Participants in this condition \( (n = 124; \text{ 27 males, 97 females}) \) were provided with CLT compliant instructional materials consisting of process-oriented worked examples paired with each of the conventional algebra problems to be solved. The key processes in each worked example were highlighted and an explanation of the procedure was written next to each step (as shown in Figure 5.1). The worked examples were incorporated into the worksheet in order to avoid split-attention effects. The experimental materials are explained in more detail in the next section and the complete set of materials for the CLT compliant condition can be found in Appendix K.
**Example**

2. Solve for $a$  \[ a + 4 = 15 \]

\[
\begin{align*}
    a + 4 + 4 &= 15 - 4 \\
    a &= 11
\end{align*}
\]

**Question**

Solve for $y$  \[ y + 7 = 24 \]

\[
\begin{array}{c}
\hline
\text{SOLUTION} \\
\hline
\text{____________________________} \\
\text{____________________________} \\
\text{____________________________}
\end{array}
\]

*Figure 5.1.* Sample worked example and problem to solve from CLT compliant instructional materials.

**CLT non-compliant Condition**

Participants in this condition ($n = 128$; 36 male, 92 female) were provided with CLT non-compliant instructional materials. Participants were required to solve the same mathematics problems as participants in Condition 1. However, each problem was presented as a conventional problem to solve, as shown in Figure 5.2.
The CLT non-compliant instructional materials did not contain worked examples paired with each problem participants were required to attempt, as they did in the CLT compliant condition. Instead, a separate coloured A4 sheet was distributed with eight product-oriented worked examples similar to those tasks to be completed, to which participants were able to refer. Key processes in the product-oriented worked examples provided were not highlighted, nor were written explanations for each step provided. This sheet provided participants with generic product-oriented worked examples as a guide for the conventional algebra problems to be solved. A product-oriented worked example is provided in Figure 5.3. Experimental materials are explained further in the next section and a complete set of materials for the CLT non-compliant condition can be found in Appendix L. The separate sheet of product-oriented worked examples can be found in Appendix M.

\[
\begin{align*}
3a + 5 &= 14 \\
3a + 5 - 5 &= 14 - 5 \\
3a &= 9 \\
3a ÷ 3 &= 9 ÷ 3 \\
a &= 3
\end{align*}
\]

*Figure 5.2. Sample problem to solve from CLT non-compliant instructional materials.*

*Figure 5.3. A sample of a non-paired product-oriented worked example from the separate A4 sheet accompanying CLT non-compliant instructional materials.*
A number of factors contribute to the non-compliance of the instructional materials to CLT in this condition. The worked examples were presented in random order, not in order of increasing complexity and were not paired with the task being completed by participants. In addition, the sheet was distributed as a separate piece of paper. Therefore, there was a split attention component as a result of the search for the appropriate worked example due to some movement required back and forth between the worked examples and the problems to be solved. As such the instructional materials were provided with evident split-attention – thus being considered CLT non-compliant. Finally, the provision of product-oriented worked examples in contrast to process-oriented worked examples was inferior in design due to the absence of instructional explanations and without structural features highlighted (van Gog et al., 2008).

5.2.4 Experimental Materials

Some adjustments to the structure and content of experimental materials from Experiment 1 were necessary. The following amendments were made to the experimental materials for Experiment 2:

• Additional written instructions, page dividers to clearly mark the beginning of each new section and an explanation of the scales used in the questionnaires were included to ensure a clear understanding of requirements for participants and so they could correctly identify their response on likert scales. These were included as it was considered more reliable than verbal instructions alone given the large lecture group participating in the experiment;

• Following consultation with the course lecturer, inclusion of less complex maths tasks throughout to accommodate the variation in maths ability of the group and align with student expectations of the enrolled course so as not to induce any further anxiety for participants.

The instructional materials consisted of a total of 15 algebra problems (5 questions of low element interactivity, 5 questions of moderate element interactivity and 5 questions of high element interactivity) that were designed for students working towards completion of Stage 5 Mathematics outcomes from the Patterns and Algebra Strand of the NSW Education Standards Authority Mathematics K-10 Syllabus
As stated previously, the level of difficulty of the algebra problems was made in consultation with the students’ lecturer and course convenor. Feedback confirmed that the mathematics questions were consistent with course expectations and were designed according to participants’ level of expertise. Questions with low element interactivity consisted of one solution step, questions of moderate element interactivity involved two solution steps and high element interactivity solutions were comprised of two or three solution steps. The level of element interactivity was adjusted in order to correspond to level of expertise of the group, questions therefore varied in difficulty from those used in Experiment 1.

Unlike previous research associated with cognitive load theory that introduces novel content to participants (Kester et al., 2005; Paas et al., 2007), the rationale for this experiment was to use content previously learnt by participants in order to investigate the relationship between anxiety, element interactivity and CLT compliant instructional materials. The use of previously acquired knowledge in the experiment eliminated the need for pre-training, normally required with the use of novel content. As a result, there was no instructional phase as part of the experiment. However, an understanding of the worked examples and problems to be solved was required and this prior knowledge cannot be assumed to be the same for all participants. As discussed in Experiment 1, the level of element interactivity of a task is dependent on the expertise of the learner. It was therefore reasonable to assume some variation in the level of expertise of participants, and hence, some variation in the cognitive load associated with tasks at each level of element interactivity.

Although the level of difficulty of the instructional materials varied from Experiment 1, the structure of the experimental materials was the same as Experiment 1, comprising two booklets, one for the CLT compliant condition and one for the CLT non-compliant condition. As for Experiment 1, these experimental materials consisted of two parts:

Part 1 measured participants’ baseline mathematics anxiety using the Abbreviated Mathematics Anxiety Scale (AMAS) (see Appendices K and L).
Part 2 included the instructional materials, as well as measures of the dependent variables.

As for Experiment 1, Part 2 comprised three sections: Section A, Section B and Section C. Each section consisted of five algebra problems (with a maximum possible score of 10) followed by a questionnaire for participants to complete. Element interactivity increased as the participant progressed through each section. Participants recorded their personal start and finish time for each section using a timer projected onto a screen in the lecture theatre and no time constraints were imposed. In total, participants completed 15 problems (5 each of low, moderate and high element interactivity) and 3 measures of cognitive load and anxiety (1 each following low, moderate and high element interactivity problems) during the testing phase.

The five algebra problems to be solved in each section were followed by an identical short questionnaire which participants were required to complete, the same as that used in Experiment 1. These questions provided subjective feedback regarding task difficulty, mental effort, and anxiety related to the task. The questionnaire following each set of maths questions consisted of 2 instruments:

1. Six items reporting participants’ subjective ratings of:
   • The mental effort required to complete the task;
   • The difficulty of the task;
   • The level of anxiety experienced while completing the task;
   • The level of satisfaction with performance on a task;
   • The level of importance placed on the task;
   • The level of engagement experienced while completing the task.
   Participant responses were recorded on a 9-point likert scale ranging from 1 (extremely low) to 9 (extremely high).

2. Ten items measuring different types of cognitive load (ICL, ECL and GCL) answered on a 11-point Likert Scale ranging from 0 (not at all the case) to 10 (completely the case).
Further details of these experimental materials can be found in Experiment 1 (refer to section 4.2.4).

5.2.5 Procedure

The procedure for Experiment 2 was the same as for Experiment 1 (Section 4.2.5) and is briefly explained here again for convenience. Participants were randomly assigned to one of two instructional design conditions (CLT compliant and CLT non-compliant). Random allocation to one of two conditions resulted from booklets handed out in random order whilst ensuring approximately even numbers of each booklet were distributed. The experiment was conducted for participants in both conditions at the same time. The three phases to the experiment were the same as in Experiment 1. All participants completed the experiment in the 2 hours allowed.

Phase 1: Introduction

Participants were each given one booklet containing all of the testing materials (See Appendices K and L). All participants, as a minimum, had at some stage previously completed course work on the given tasks. The minimum completed mathematics for any participant was Year 10, comprising the algebra component of the NSW mathematics syllabus for Stage 5.

All students participating in the study were in one room under supervision of the researcher. Instructions were provided for participants verbally and on the front page of the booklet. The script used to provide instructions was the same as that used in Experiment 1 (see Appendix I). Participants were able to proceed at their own pace for each section and were asked to record their start and finish time for each section of the maths problems using the timer provided on the screen at the front of the lecture theatre. Participants moved on to each new section, identified with dividers in the booklet, in order. Participants moved on to each new section as a group when all had completed the previous task. Participants were asked not to go back and make any changes once each section was completed and the time was recorded. They were asked to complete all answers in the booklet provided and include all working steps in their solution for each
problem. Participants were permitted to use calculators in order to minimise calculation errors and focus on the understanding of algebraic concepts. Sufficient time allocation ensured no additional anxiety was imposed on the participants. In addition, students were assured that they were not being tested in any way and the worksheets completed would not form part of their assessment for their course. Once the instruction prior to the task was completed, no further verbal directions or feedback was provided for the students.

**Phase 2: Baseline measure of anxiety and demographic / expertise questions**
Participants completed the Abbreviated Mathematics Anxiety Scale (AMAS), to determine a baseline measure of anxiety (See Part 1, Appendix K and L). Participants’ level of anxiety was used to allocate participants to test groups. Mathematics expertise was established according to data provided by the participants regarding their highest level of secondary school mathematics successfully completed. Expertise has an effect on the cognitive load associated with a task and therefore should be considered in the analysis of CLT compliant materials for anxious students.

**Phase 3: Completion of Maths Tasks and Questionnaires**
Instructional materials for this experiment were based on the Stage 5 outcomes of the NSW Mathematics syllabus. Participants were required to complete a worksheet (see Appendices K and L) that included a number of algebraic equations. A measure of the number of correct responses was made, and marks allocated according to the marking scheme outlined previously (see Section 4.2.4). Participants recorded their start and finish times for each set of algebra problems. Participants in both conditions completed the same questionnaires after the algebra questions in each section, which provided subjective measures of cognitive load, anxiety, difficulty, importance, satisfaction and engagement related to the task at each level of element interactivity. To ensure confidentiality, data from each booklet was recorded using only a code to identify the student as a participant of the CLT compliant condition or CLT non-compliant condition only.
5.3 DATA ANALYSIS

The strategy for data analysis was the same as that implemented for Experiment 1 and is explained below. Data analysis consisted of two phases. The first phase consisted of preliminary analysis of data to determine inter-rater reliability, ensuring consistency, followed by identification of participants as low and high baseline maths anxiety in each Instructional Design Condition. It was not necessary to test the normality of data as the sample size for the study was sufficiently large to assume normal distribution of scores. The second phase of data analysis comprised the analysis dependent variables, and consisted of three parts. Firstly, analysis of participants’ performance and subjective measures of cognitive load across the instructional conditions was undertaken by conducting a 2 (Instructional Design Condition) x 3 (Element Interactivity Condition) factorial analysis. This was followed by analysis using Pearson’s Correlation coefficient to investigate the relationship between participants’ baseline maths anxiety and cognitive load regardless of instructional condition, then across conditions using a 2 (Instructional Design Condition) X 2 (Baseline Maths Anxiety) ANOVA. Part 3 considered participants’ baseline maths anxiety in the analysis of performance scores, subjective measures of cognitive load and perceived task anxiety, and additional dependent variables as necessary (for example, expertise due to its impact on cognitive load and element interactivity). This analysis was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 3 (Element Interactivity Condition) factorial analysis.

An elaboration of how these two phases of data analysis were conducted is provided below.

5.3.1 Preliminary Analysis

Inter-rater reliability

Participant booklets were marked by two independent scorers, using the marking criteria provided (refer to Section 5.2.4). On completion of marking, a comparison of marks allocated by the two independent scorers was undertaken to assess the accuracy and consistency of results between markers. Calculation of Pearson Correlation
demonstrated an inter-rater reliability $r = 1$, indicating a perfect correlation between markers (Gao, 2012).

**No exclusion of participants**
All participants successfully completed all parts of the experimental materials and so data collected from all participants were included in the study.

**Identifying high and low anxious participants**
The approach used in Experiment 2 to identify low and high anxiety participants was the same as that used in Experiment 1. Unlike Experiment 1, homogeneous groups in the CLT compliant condition and the CLT non-compliant condition were established for both low and high anxiety participants.

Participants received either CLT compliant experimental materials or CLT non-compliant experimental materials. An individual’s baseline level of anxiety was calculated and identified according the Abbreviated Maths Anxiety Scale (AMAS). Each individual’s score was composed of the sum of their subjective responses to 9 questions to provide a total anxiety score with a minimum of 9 and maximum of 45 possible (Hopko et al., 2003a).

As in Experiment 1, terciles were used to determine the low and high anxiety groups. Participants were divided into three groups and categorized as low or high maths anxious based on the scores obtained on the AMAS. High maths anxious participants were those with AMAS scores in the top third of scores in each condition and low maths anxious participants were those with AMAS scores in the bottom third of scores for each condition. Participants in the middle third were not included in Part 3 of the analysis for anxiety groups. Using this criterion to categorise participants, an independent samples t-test was conducted to compare the AMAS scores of those with low and high anxiety in the CLT compliant condition and the AMAS scores of those with low and high anxiety in the CLT non-compliant condition. There was a significant difference between the AMAS scores for students in the low and high anxiety groups for both the CLT compliant condition, $t(94) = 19.93, p = .001$, and the CLT non-compliant condition, $t(97) = 18.08, p = .001$. Table 5.1 illustrates the AMAS scores for...
low and high anxiety participants in both the CLT compliant and CLT non-compliant instructional materials conditions. Scores ranged from 9 to 36 for the CLT compliant condition and from 9 to 41 for the CLT non-compliant condition. These scores were then divided into terciles. High and low anxious participants were therefore identified not solely on their AMAS score, but where that score placed them within the range of scores for individuals in the same condition. Responses determined whether participants were categorized as low or high anxiety maths anxious individuals.

Table 5.1
*Baseline AMAS Scores For Participants in Each Condition Identifying Upper And Lower Terciles*

<table>
<thead>
<tr>
<th>AMAS Score For Each Condition</th>
<th>CLT compliant</th>
<th>CLT non-compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Anxiety (LA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Tercile Range</td>
<td>9-22</td>
<td>9-22</td>
</tr>
<tr>
<td>LA n</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>LA Mean</td>
<td>18.69</td>
<td>18.69</td>
</tr>
<tr>
<td>LA SD</td>
<td>3.04</td>
<td>3.25</td>
</tr>
<tr>
<td>Moderate Anxiety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Tercile Range</td>
<td>23-26</td>
<td>23-26</td>
</tr>
<tr>
<td>n</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>High Anxiety (HA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Tercile Range</td>
<td>27-36</td>
<td>27-41</td>
</tr>
<tr>
<td>HA n</td>
<td>51</td>
<td>48</td>
</tr>
<tr>
<td>HA Mean</td>
<td>30.00</td>
<td>30.01</td>
</tr>
<tr>
<td>HA SD</td>
<td>2.52</td>
<td>2.96</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>9-36</td>
<td>9-41</td>
</tr>
<tr>
<td>Total n</td>
<td>124</td>
<td>127</td>
</tr>
<tr>
<td>Total Mean</td>
<td>24.67</td>
<td>24.22</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.57</td>
<td>5.74</td>
</tr>
</tbody>
</table>
Following analysis of the data collected, highly anxious individuals were identified as those in the upper tercile of anxiety scores in each condition: 99 participants from a total of 252. Those with scores identical to the cut-off were included in the group. This translated to AMAS scores of between 27 and 36 for the CLT compliant instruction group (a total of 51 participants) and between 27 and 41 for the CLT non-compliant instruction group (a total of 48 participants). There were 96 participants identified as low anxious. Low anxious participants were identified as those in the lower tercile of anxiety scores in each condition. This translated to AMAS scores of between 9 and 22 for both the CLT compliant instructional condition and the CLT non-compliant instructional condition – a total of 45 and 51 participants respectively. The higher number of participants included in each tercile was a result of the addition of participants scoring the same as the cut-off point beyond the tercile limits.

There was no significant difference in the baseline anxiety scores of participants in the CLT compliant and CLT non-compliant instructional conditions, \( F(1,249) = 0.388, p = .534 \). There was no significant difference in the AMAS scores in the CLT compliant and CLT non-compliant instructional conditions for those identified as low anxiety, \( t(94) = 0.011, p = .991 \), or the AMAS scores in the CLT compliant and CLT non-compliant instructional conditions for those identified as high anxiety, \( t(97) = 0.019, p = .985 \). That is, the baseline anxiety measure for both low and high anxiety was consistent between conditions.

5.3.2 Analysis of Dependent Variables

The second phase of analysis was the analysis of dependent variables and was structured in the same way as in Experiment 1. All analyses were preceded by computation of descriptive statistics (mean, standard deviation) for all measures of performance, cognitive load and anxiety. There were three parts to the analysis undertaken, each part described in more detail in Section 4.3.2:

- Part 1: a 2 (Instructional Design) x 3 (Element Interactivity) analysis of variance (ANOVA) was conducted to compare the effectiveness of CLT compliant materials compared to CLT non-compliant material;
• Part 2: Pearson’s Correlation Co-efficient was calculated to determine the nature of the relationship between baseline maths anxiety and cognitive load, as well as a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) ANOVA to confirm findings across instructional design conditions;
• Part 3: a 2 (Instructional Design) x 2 (Baseline Anxiety) x 3 (Element Interactivity) analysis of variance (ANOVA) was calculated on participants’ performance scores, cognitive load ratings and perceived task anxiety ratings to investigate main effects of participants’ baseline maths anxiety.

As for experiment 1, any analyses that indicated significant effects were analysed further using 2 (experimental group or level of element interactivity) x 2 (dependent variable) ANOVA, t-tests and Cohen’s d. Likewise, additional findings related to participants’ perceived task anxiety in terms of expertise was conducted and is discussed in Section 5.4.3.4.1. Results were examined for participants’ problem-solving performance scores, cognitive load ratings and perceived task anxiety ratings. Significant interactions between element interactivity, instructional conditions and baseline maths anxiety were then analysed using T-tests and/or correlations. Analyses involving several t-tests were performed, a Bonferroni correction (α = 0.05) was adopted. Otherwise, t-tests were conducted between 2 groups only to avoid Type 1 errors requiring Bonferroni correction. In addition, descriptive statistics for participants’ subjective ratings of task difficulty, task importance and task satisfaction were analysed. A full set of these results can be found in Appendix P (Table P1). These ratings were reported in each section following completion of each set of maths questions and subjective ratings were measured using the same 9-point likert scale as the Cognitive Load Subjective Rating Scale. Details of additional findings related to these variables are found in Appendix P.

5.4 RESULTS

The results are presented in a similar way to Experiment 1, that is, in three parts according to the research questions, and as discussed in Section 5.3.2. Analyses of variables beyond those addressed specifically in the research questions have been
included as additional findings as appropriate, with full details of the analyses for these additional findings available in Appendix P.

5.4.1 Part 1 – Performance and Cognitive Load across Instructional Conditions

Research Question 1 was concerned with a comparison of participants’ performance scores and ratings of cognitive load for problems of high element interactivity when using either CLT compliant instructional materials or CLT non-compliant instructional materials. This analysis was undertaken to confirm previous research findings related to the negative impact of CLT non-compliant instructional materials and tasks of high element interactivity on participants’ performance scores and subjective ratings of cognitive load. Analysis did not include consideration of participants’ level of mathematics anxiety in Research Question 1.

5.4.1.1 Performance across Instructional Conditions

Performance scores were calculated for low, moderate, high element interactivity, each consisting of 5 questions and with a possible maximum score of 10, combining to give a total score out of 30. Descriptive Statistics for performance scores in the CLT compliant and CLT non-compliant condition are shown in Table 5.2.

Table 5.2
Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Conditions

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CLT compliant n=124</th>
<th>CLT non-compliant n=127</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performance Mean (SD)</td>
<td>Performance Mean (SD)</td>
</tr>
<tr>
<td>Low (/10)</td>
<td>8.94 (1.58)</td>
<td>9.20 (1.27)</td>
</tr>
<tr>
<td>Moderate (/10)</td>
<td>8.84 (1.99)</td>
<td>8.90 (2.05)</td>
</tr>
<tr>
<td>High (/10)</td>
<td>7.55 (3.01)</td>
<td>7.25 (3.00)</td>
</tr>
<tr>
<td>Total (/30)</td>
<td>25.33 (5.44)</td>
<td>25.35 (5.27)</td>
</tr>
</tbody>
</table>
Overall, the total performance scores for the CLT compliant condition and the CLT non-compliant condition were not significantly different, \( F(1,249) = 0.001, p = .972 \).

**Performance Scores and Element Interactivity**

There were no significant differences in performance scores between the CLT compliant condition and the CLT non-compliant condition for tasks of low \( (F(1,249) = 2.076, p = .151) \), moderate \( (F(1,249) = 0.053, p = .817) \) or high \( (F(1,249) = 0.611, p = .435) \) element interactivity.

Table 5.2 shows for both the CLT compliant condition and the CLT non-compliant condition, at higher levels of element interactivity, there was a corresponding decrease in performance scores. This effect was significant only between performance scores for tasks of moderate element interactivity and tasks of high element interactivity for both conditions. For the CLT compliant condition, there was no significant difference between performance scores for tasks of low element interactivity and tasks of moderate element interactivity, \( t(123) = 0.620, p = .536 \) but a significant difference between tasks of moderate element interactivity and tasks of high element interactivity, \( t(123) = 6.122, p < .001 \). For the CLT non-compliant condition there was no significant difference between performance scores for tasks of low element interactivity and tasks of moderate element interactivity, \( t(126) = 1.801, p = .074 \) but a significant difference between tasks of moderate element interactivity and tasks of high element interactivity, \( t(126) = 7.710, p < .001 \). In the CLT compliant condition, element interactivity had a medium effect on performance scores \( (d = 0.58) \) and in the CLT non-compliant condition, element interactivity had a large effect on performance scores \( (d = 0.84) \). Although t-tests did not show a significant difference between performance scores at low and moderate element interactivity in both the CLT compliant condition and the CLT non-compliant condition, there was, however, a significant negative correlation between performance scores and element interactivity \( (r = -.292, n = 585, p < .001) \). This supports previous research that an increase in the level of element interactivity results in a concomitant reduction in performance scores (Sweller, 1994). Furthermore, high performance scores for participants in both the CLT compliant condition and the CLT non-compliant condition for tasks of low and moderate element interactivity suggest redundancy of CLT compliant instructional materials for simple tasks (Chandler & Sweller, 1991).
5.4.1.2 Cognitive Load across Instructional Conditions

Participants’ ratings of cognitive load were measured using two scales. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992), which measures overall total cognitive load. Cognitive load was also measured using an alternate cognitive load measurement scale, devised by Leppink et al., (2013), referred to here as the Cognitive Load Differentiating Scale (CLDS). This scale was specifically designed to differentiate between individual components of cognitive load i.e. intrinsic, extraneous and germane cognitive load, representing the total cognitive load for each task. The results for both subjective cognitive load scales are presented below.

5.4.1.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992)

Mental effort ratings were calculated for low, moderate and high element interactivity using the CLSRS. A score between 1 and 9 was recorded on a likert scale for “Rate the mental effort required to complete the task”. Total mental effort ratings for each condition were calculated by addition of mean mental effort ratings for tasks of low, moderate and high element interactivity. Descriptive statistics for mental effort ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 5.3.
Table 5.3
Descriptive Statistics – Mental Effort Rating (CLSRS) for CLT compliant and CLT non-compliant Conditions

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CLT compliant n = 124</th>
<th>CLT non-compliant n = 127</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mental Effort Rating</td>
<td>Mental Effort Rating</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low (/9)</td>
<td>2.95 (1.61)</td>
<td>2.71 (1.50)</td>
</tr>
<tr>
<td>Moderate (/9)</td>
<td>4.13 (2.08)</td>
<td>3.84 (1.79)</td>
</tr>
<tr>
<td>High (/9)</td>
<td>5.21 (2.14)</td>
<td>5.04 (1.95)</td>
</tr>
<tr>
<td>Total (/27)</td>
<td>12.29 (5.33)</td>
<td>11.59 (4.64)</td>
</tr>
</tbody>
</table>

Table 5.3 shows the mean total mental effort rating was higher for participants using CLT compliant materials compared to those using CLT non-compliant materials. This difference was not significant, $F(1,249) = 1.233, p = .268$.

Mental Effort Rating and Element Interactivity

There were no significant differences in mental effort ratings between the CLT compliant condition and the CLT non-compliant condition for tasks of low ($t(249) = 1.236, p = .218$), moderate ($t(249) = 1.185, p = .237$), or high ($t(249) = 0.644, p = .520$) element interactivity. Results showed that the higher the level of element interactivity, the higher the participants’ perceived mental effort for both the CLT compliant condition and the CLT non-compliant condition. For the CLT compliant condition, element interactivity had a large effect on participants’ mental effort ratings ($d = 1.19$). For the CLT compliant condition, there was a significant difference between mental effort ratings for tasks of low and moderate element interactivity, $t(123) = 8.948, p < .001$, between mental effort ratings for tasks of moderate and high element interactivity, $t(123) = 9.364, p < .001$ and between mental effort ratings for tasks of low and high element interactivity, $t(123) = 9.735, p < .001$ and between mental effort ratings for tasks of low and high element interactivity, $t(123) = 9.364, p < .001$. Likewise, for the CLT non-compliant condition, element interactivity had a large effect on participants’ mental effort ratings ($d = 1.34$). For the non-CLT compliant condition there was a significant difference between mental effort ratings between for tasks of low and moderate element interactivity, $t(126) = 9.837, p < .001$, between mental effort ratings for tasks of
moderate and high element interactivity, \( t(126) = 10.356, p < .001 \) and between mental effort ratings for tasks of low and high element interactivity, \( t(126) = 10.673, p < .001 \). Therefore, at higher levels of element interactivity, the effort, or load, associated with the task was greater. There was a significant positive correlation between element interactivity and effort ratings: \( r = .408, n = 585, p < .001 \). This supports previous research that asserts that a participant’s subjective rating of cognitive load is greater for high levels of element interactivity (Paas & van Merriënboer, 1993).

5.4.1.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

Ratings for each component of cognitive load were measured using the Cognitive Load Differentiating Scale (Leppink et al., 2013). Cognitive Load ratings were recorded for solving maths problems of low, moderate and high element interactivity. The CLDS consists of 10 items: 3 related to ICL, 3 related to ECL and 4 related to GCL. Each item was measured using an 11-point likert scale ranging from 0 to 10. The total load for the task in each instructional condition was also found by adding the cognitive load ratings for low, moderate and high element interactivity tasks, for each component of cognitive load. For the purposes of this analysis, results focused on extraneous cognitive load only.

Three items measuring ECL (numbers 4 – 6 of the CLDS) created a possible total score between 0 and 30, with higher scores indicating a higher load. Descriptive statistics for ECL ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 5.4.
Table 5.4

Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Conditions

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CONDITION</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLT compliant $n = 124$</td>
<td>CLT non-compliant $n = 127$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECL Mean (SD)</td>
<td>ECL Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Low (/30)</td>
<td>3.72 (4.73)</td>
<td>2.65 (3.14)</td>
<td></td>
</tr>
<tr>
<td>Moderate (/30)</td>
<td>4.53 (5.34)</td>
<td>3.05 (4.40)</td>
<td></td>
</tr>
<tr>
<td>High (/30)</td>
<td>5.42 (7.31)</td>
<td>3.22 (4.92)</td>
<td></td>
</tr>
<tr>
<td>Total (/90)</td>
<td>13.67 (15.08)</td>
<td>8.91 (10.94)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.4 shows participants’ ECL ratings were significantly higher in the CLT compliant condition than in the CLT non-compliant condition, $F(1,249) = 8.208, p = .005$.

**ECL Ratings and Element Interactivity**

ECL ratings for the CLT compliant condition were significantly higher than ECL ratings for the CLT non-compliant condition at low $F(1,249) = 4.50, p = .034$, moderate $F(1,249) = 5.80, p = .017$ and high $F(1,249) = 7.85, p = .005$ element interactivity. This finding does not support previous research that suggests the use of worked examples, that is CLT compliant instructional material, reduces ECL for complex tasks (Paas et al., 2003b). The CLT compliant condition reported greater ECL compared to the CLT non-compliant condition. This difference occurs at all levels of element interactivity, the greatest difference occurring at high element interactivity, as shown in Figure 5.4.
In both the CLT compliant condition and the CLT non-compliant condition, participants’ ratings of ECL were higher at higher levels of element interactivity. An increase from low element interactivity to high element interactivity had a significant effect on participants’ ratings of ECL in the CLT compliant condition, $t(124) = 2.177$, $p = .030$, with a small effect size ($d = 0.28$). However, in the CLT non-compliant condition, a change in element interactivity from low to high did not have a significant effect on participants’ rating of ECL, $t(127) = 1.109$, $p = .268$, with a small effect size ($d = 0.14$). This indicated only a minor difference in ECL reported as according to cognitive load theory, element interactivity is indicative of ICL, and is independent of ECL. For both conditions, ECL ratings were highest for tasks of high element interactivity.

5.4.1.3 Summary of Part 1 Results

Results showed that participants achieved significantly higher performance scores when solving problems of low element interactivity compared to moderate element interactivity compared to high element interactivity in both the CLT compliant condition and the CLT non-compliant condition. However, results showed that there

Figure 5.4. Graph of extraneous cognitive load for CLT compliant condition and CLT non-compliant condition.
were no significant differences in the performance scores for participants using CLT compliant materials compared to participants using CLT non-compliant materials. Hypothesis 1, learners using CLT compliant instructional materials will outperform learners using CLT non-compliant instructional materials when solving problems of high element interactivity, in accordance with previous CLT research, was not supported. As expected, results showed that participants reported lower cognitive load when solving problems of low element interactivity compared to high element interactivity. That is, the cognitive load associated with a task corresponds with the complexity of the task. However, results showed that there were no significant differences in the ratings of mental effort for participants using CLT compliant materials compared to participants using CLT non-compliant materials when analysing mental effort ratings using the CLSRS (Paas, 1992). Furthermore, ECL ratings were significantly higher when using CLT compliant materials compared to CLT non-compliant materials when analysing subjective ratings of extraneous cognitive load from the CLDS (Leppink et al., 2013). Thus Hypothesis 2, that predicted learners using CLT compliant instructional materials would report lower cognitive load compared to learners using CLT non-compliant instructional materials when solving problems of high element interactivity, in accordance with previous CLT research, was not supported.

5.4.1.4 Additional Findings for Validation of Materials

The CLDS also measured the intrinsic and germane cognitive load of a task. As in Experiment 1, analysis of these results allowed validation of our experimental materials, ICL for determining levels of element interactivity and GCL for effectiveness of CLT compliant instructional materials. Descriptive statistics for these measures can be found in Appendix P (Table P2 and Table P3 respectively).

At higher levels of element interactivity, participants reported higher ICL ratings in both the CLT compliant condition and the CLT non-compliant condition. Participants in both conditions reported ICL was higher at high element interactivity than at moderate element interactivity, which in turn was higher than at low element interactivity. These results support previous findings that high element interactivity incurs a high intrinsic
cognitive load. Calculation of Cohen’s $d$ indicated an increase in element interactivity from low to high had a large effect size for both the CLT compliant condition, $d = 0.92$ and the CLT non-compliant condition, $d = 0.85$. The correlation between intrinsic cognitive load and element interactivity was positive and significant: $r = .336$, $n = 585$, $p < .001$. This was to be expected as ICL is directly related to the level of element interactivity involved in a task. This confirms that the experimental instructional materials successfully differentiated between tasks of varying levels of element interactivity.

As shown in Figure 5.5, the use of CLT compliant instructional materials allowed participants to engage significantly more germane resources than the use of CLT non-compliant materials.

![Germane Cognitive Load](image)

*Figure 5.5.* Germane cognitive load for CLT compliant and CLT non-compliant conditions.

Consistent with analyses in Experiment 1, this difference in GCL between the CLT compliant condition and CLT non-compliant condition was significant for tasks of low element interactivity, $F(1,249) = 7.995$, $p = .005$, moderate element interactivity, $F(1,249) = 6.45$, $p = .012$ and high element interactivity, $F(1,249) = 6.09$, $p = .014$ as well as for the total measure of GCL, $F(1,249) = 8.083$, $p = .005$. Participants using CLT compliant instructional materials reported greater GCL compared to those using
CLT non-compliant instructional materials, indicative of greater understanding of the task. In addition, when using CLT compliant instructional materials, as element interactivity increased, so too did the investment of germane resources to accommodate the increased complexity of the task.

### 5.4.2 Part 2 – Relationship between Cognitive Load and Baseline Mathematics Anxiety

Part 2 of the analysis of dependent variables, which focused on addressing Research Question 2, investigated the relationship between participants’ cognitive load ratings and their baseline maths anxiety, indicated by their AMAS score. This analysis was conducted to determine whether participants with high baseline mathematics anxiety reported higher cognitive load than participants with low baseline mathematics anxiety.

Descriptive Statistics and effect sizes for the mental effort and cognitive load ratings reported for low and high anxiety participants at low and high element interactivity are presented in Table 5.5.

<table>
<thead>
<tr>
<th></th>
<th>Low Element Interactivity</th>
<th>High Element Interactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Anxiety</td>
<td>High Anxiety</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Effect Size (d)</td>
</tr>
<tr>
<td></td>
<td>Low Anxiety</td>
<td>High Anxiety</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Effect Size (d)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Effort</th>
<th>ICL</th>
<th>ECL</th>
<th>GCL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.17 (1.18)</td>
<td>3.37 (4.15)</td>
<td>2.34 (3.30)</td>
<td>8.42 (9.14)</td>
</tr>
<tr>
<td></td>
<td>3.41 (1.74)</td>
<td>7.21 (6.50)</td>
<td>4.18 (4.64)</td>
<td>11.21 (8.74)</td>
</tr>
<tr>
<td></td>
<td>0.83</td>
<td>0.70</td>
<td>0.46</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>4.44 (1.89)</td>
<td>8.52 (7.13)</td>
<td>2.97 (5.15)</td>
<td>9.41 (9.48)</td>
</tr>
<tr>
<td></td>
<td>5.94 (2.05)</td>
<td>14.89 (8.72)</td>
<td>6.15 (7.68)</td>
<td>12.39 (9.92)</td>
</tr>
<tr>
<td></td>
<td>0.76</td>
<td>0.80</td>
<td>0.49</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Table 5.5 shows at both low and high element interactivity, anxiety had a medium to large effect on participants’ mental effort ratings, intrinsic cognitive load and extraneous
cognitive load. Although high anxiety participants reported higher germane cognitive load, the effect size was small for tasks of both low and high element interactivity. Analysis using a one-way ANOVA revealed that participants’ baseline maths anxiety had a significant effect on all ratings of cognitive load for tasks of low and high element interactivity. For tasks of low element interactivity, high anxiety participants reported significantly higher mental effort ratings ($F(1,193) = 36.159, p < .001$), ICL ratings ($F(1,193) = 26.099, p < .001$), ECL ratings ($F(1,193) = 10.992, p = .001$), and GCL ratings ($F(1,193) = 5.428, p = .021$), compared to low anxiety participants. Likewise, for tasks of high element interactivity, high anxiety participants reported significantly higher mental effort ratings ($F(1,193) = 29.776, p < .001$), ICL ratings ($F(1,193) = 32.857, p < .001$), ECL ratings ($F(1,193) = 12.007, p = .001$), and GCL ratings ($F(1,193) = 5.048, p = .026$), compared to low anxiety participants.

Pearson’s correlation coefficient was calculated between participants’ baseline maths anxiety and effort ratings from the CLSRS (Paas, 1992) and between participants’ baseline anxiety and components of cognitive load (ICL, ECL and GCL) from the CLDS (Leppink et al., 2013) for tasks of low, moderate and high element interactivity. These results are presented in Table 5.6.

Table 5.6

<table>
<thead>
<tr>
<th></th>
<th>Low EI</th>
<th>Moderate EI</th>
<th>High EI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLSRS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>$r(251) = .432, p &lt; .001$</td>
<td>$r(251) = .420, p &lt; .001$</td>
<td>$r(251) = .395, p &lt; .001$</td>
</tr>
<tr>
<td><strong>CLDS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICL</td>
<td>$r(251) = .382, p &lt; .001$</td>
<td>$r(251) = .399, p &lt; .001$</td>
<td>$r(251) = .413, p &lt; .001$</td>
</tr>
<tr>
<td>ECL</td>
<td>$r(251) = .214, p &lt; .001$</td>
<td>$r(251) = .223, p &lt; .001$</td>
<td>$r(251) = .229, p &lt; .001$</td>
</tr>
<tr>
<td>GCL</td>
<td>$r(251) = .138, p = .028$</td>
<td>$r(251) = .121, p = .056$</td>
<td>$r(251) = .115, p = .069$</td>
</tr>
</tbody>
</table>

Table 5.6 shows at all levels of element interactivity, a significant positive correlation exists between participants’ AMAS score and all measures of cognitive load, with the exception of GCL. As participants’ baseline measure of maths anxiety increased, so too did their subjective measure of mental effort (CLSRS) (Paas, 1992) and their subjective
measure of ICL and ECL (Leppink et al., 2013). Overall, these results showed that high baseline maths anxiety was strongly, positively correlated with participants’ subjective measures of cognitive load, with correlations being significant for tasks of low, moderate and high element interactivity (with the exception of GCL). Thus, Hypothesis 3, that predicted participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety, was supported.

The impact of participants’ baseline maths anxiety on each of these measures was investigated for both the CLT compliant condition and the CLT non-compliant condition. Additional analysis was conducted using a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) analysis of variance (ANOVA) for participants’ perceived cognitive load measures. This allowed a comparison of participants’ cognitive load ratings for participants with both low and high baseline maths anxiety in both the CLT compliant condition and the CLT non-compliant condition. For tasks of low and high element interactivity, participants’ baseline measure of maths anxiety (AMAS score) was found to have a significant main effect on all measures of effort and cognitive load. At low element interactivity, anxiety was found to have a significant main effect on participants’ effort rating, $F(1,192) = 33.24, p < .001$, participants’ measure of ICL, $F(1,192) = 23.99, p < .001$, participants’ measure of ECL, $F(1,192) = 10.31, p = .002$ and participants’ measure of GCL, $F(1,192) = 4.43, p = .037$. Similarly, at high element interactivity, anxiety was found to have a significant main effect on participants’ effort rating, $F(1,192) = 33.24, p < .001$, participants’ measure of ICL, $F(1,192) = 31.28, p < .001$, participants’ measure of ECL, $F(1,192) = 11.51, p = .001$ and participants’ measure of GCL, $F(1,192) = 4.27, p = .040$. Importantly, the use of CLT compliant instructional materials compared to CLT non-compliant materials was found to have a significant effect on the investment of germane resources at both low element interactivity, $F(1,192) = 7.135, p = .008$, and high element interactivity, $F(1,192) = 5.338, p = .022$. Therefore, despite the correlation between baseline maths anxiety and GCL not being significant at high element interactivity (see Table 5.6), participants reported greater investment of germane resources when using CLT compliant materials.
Further analysis using t-tests was completed to investigate the relationship between instructional materials and participants’ baseline anxiety on participants’ measures of cognitive load. The differences in effort ratings and cognitive load measures between participants with low anxiety and high anxiety were also significant, with the exception of GCL. Results that showed significant differences in measures of cognitive load between low anxiety and high anxiety participants in the CLT compliant condition, between low and high anxiety participants in the CLT non-compliant condition and for high anxiety participants in the CLT compliant condition compared to the CLT non-compliant condition are presented in Table 5.7.

Table 5.7

<table>
<thead>
<tr>
<th>Significant Results From T-Tests Comparing Participants’ Baseline Anxiety And Instructional Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>CCLA V CCHA</strong></td>
</tr>
<tr>
<td>Mental Effort Rating</td>
</tr>
<tr>
<td>$t(101) = 4.873, p &lt; .001$</td>
</tr>
<tr>
<td>$t(101) = 4.328, p &lt; .001$</td>
</tr>
<tr>
<td>ICL</td>
</tr>
<tr>
<td>$t(101) = 4.328, p &lt; .001$</td>
</tr>
<tr>
<td>$t(101) = 4.685, p &lt; .001$</td>
</tr>
<tr>
<td>ECL</td>
</tr>
<tr>
<td>$t(101) = 3.141, p = .002$</td>
</tr>
<tr>
<td>$t(101) = 2.786, p = .006$</td>
</tr>
<tr>
<td><strong>CNLA V CNHA</strong></td>
</tr>
<tr>
<td>Mental Effort Rating</td>
</tr>
<tr>
<td>$t(104) = 3.339, p = .001$</td>
</tr>
<tr>
<td>$t(104) = 2.428, p = .017$</td>
</tr>
<tr>
<td>ICL</td>
</tr>
<tr>
<td>$t(104) = 2.944, p = .004$</td>
</tr>
<tr>
<td><strong>CCHA V CNHA</strong></td>
</tr>
<tr>
<td>Mental Effort Rating</td>
</tr>
<tr>
<td>$t(125) = 2.363, p = .020$</td>
</tr>
<tr>
<td>$t(125) = 3.521, p = .001$</td>
</tr>
<tr>
<td>ICL</td>
</tr>
<tr>
<td>$t(125) = 3.053, p = .003$</td>
</tr>
<tr>
<td>ECL</td>
</tr>
</tbody>
</table>

Table 5.7 shows that when using CLT compliant materials, there was a significant difference in participants’ ratings of mental effort, ICL and ECL for high anxiety participants compared to low anxiety participants for tasks of both low and high element interactivity. When using CLT non-compliant instructional materials, the difference between effort ratings for low and high anxiety participants was significant at low and high element interactivity. However, ICL ratings of high anxiety participants were significantly higher than ICL ratings of low anxiety participants when solving problems.
of high element interactivity only. For high anxiety participants, ratings of mental effort, ICL and ECL were significantly higher when using CLT compliant materials compared to CLT non-compliant materials for tasks of high element interactivity.

The results from measurement of cognitive load with both the CLSRS and the CLDS confirmed that high anxiety imposed a load on working memory causing a significant concomitant increase in mental effort, ICL and ECL. Furthermore, for participants with high maths anxiety, ratings of GCL, the load associated with investment of germane resources contributing to learning, were higher with the use of CLT compliant materials. Finally, of particular interest was the higher perceived ICL of a task for participants with high baseline maths anxiety compared to participants with low baseline maths anxiety.

5.4.3 Part 3 – Analysis incorporating Instructional Conditions and Participant Anxiety

As for Experiment 1, part 3 of the results addressed Research Questions 3 and 4, as well as the Exploratory Questions 1 and 2, and was based on participants’ baseline maths anxiety groupings within each condition. This allowed the investigation of how instructional materials designed according to CLT principles may provide support to learners with high maths anxiety.

The analysis undertaken reports findings for participants’ total scores, subjective ratings of cognitive load and subjective ratings of perceived task anxiety. Analysis considered the level of element interactivity and participants’ baseline maths anxiety. Analyses of variables beyond those addressed specifically in the research questions, such as expertise, task difficulty, task satisfaction and task importance (see Section 5.3.2) are included as additional findings as appropriate with full details of these analyses available in Appendix P.
5.4.3.1 Performance

For Research Question 3, data for participants’ performance scores were analysed based on baseline mathematics anxiety levels, that is, low and high mathematics anxiety categories in each condition. Descriptive results for these four groups are presented in Table 5.8.

Table 5.8

Descriptive Statistics – Performance with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactivity (EI)</td>
<td>CCLA n = 45</td>
</tr>
<tr>
<td>Low (/10)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>9.111 (1.480)</td>
<td>8.686 (1.86)</td>
</tr>
<tr>
<td>Moderate (/10)</td>
<td>9.422 (0.917)</td>
</tr>
<tr>
<td>High (/10)</td>
<td>8.644 (1.760)</td>
</tr>
<tr>
<td>Total (/30)</td>
<td>27.178 (3.002)</td>
</tr>
</tbody>
</table>

Table 5.8 shows at high element interactivity, mean performance scores were lower than mean performance scores at moderate element interactivity, which in turn, were lower than mean performance scores at low element interactivity under all conditions, for both low and high mathematics anxious participants using CLT compliant and CLT non-compliant instructional materials (with the exception of an erroneous result for low anxious students using CLT compliant materials that performed better at moderate element interactivity than at low element interactivity). A one-way ANOVA for performance scores confirmed a significant effect between the four groups at high element interactivity, $F(191,3) = 4.592, p = .004$. However, for tasks of high element interactivity, there was no significant difference between the performance scores of highly anxious participants in the CLT compliant condition (CCHA) and the CLT non-compliant condition (CNHA): $F(1.97) = 0.199, p = .656$. Thus, Hypothesis 4, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity, was not supported. High
anxiety had a negative effect on the performance scores of participants using both CLT compliant and CLT non-compliant materials. CLT compliant instructions did not improve the performance of highly anxious students when completing complex problems.

5.4.3.1.1 Additional Findings for Performance Results

Additional analysis revealed some notable results of high element interactivity performance scores for participants with low baseline mathematics anxiety using CLT compliant materials, similar to those found in Experiment 1. This group, the CLT compliant, low anxiety group (CCLA) achieved the highest performance score across the four groups (refer to Figure 5.6). Analysis using a 2x2x3 ANOVA showed that the CCLA group reported a statistically significant higher performance score compared to all other groups completing problems of high element interactivity, confirming findings from Experiment 1.

Calculating the effect size (using Cohen’s $d$) revealed a large effect size in performance for CCLA compared to all other groups. This is elaborated as follows:

- CCLA significantly outperformed CCHA, $F(1,94) = 13.455, p = .000 (d = .76)$. This result provides evidence that performance is negatively impacted by high baseline mathematics anxiety;
- CCLA significantly outperformed CNLA $F(1,94) = 8.905, p = .004 (d = .62)$. This result indicates that CLT compliant instructional materials supported low baseline mathematics anxiety participants when solving mathematics problems of high element interactivity;
- CCLA significantly outperformed CNHA, $F(1,91) = 11.485, p = .001 (d = .71)$. This result shows that participants with low baseline mathematics anxiety that used CLT compliant instructional materials performed better than participants with high baseline mathematics anxiety that used of CLT non-compliant instructional materials.

Collectively, these findings show that high baseline mathematics anxiety had a
significant negative impact on performance. Presenting these findings visually (see circled column in Figure 5.6) clearly illustrates the superior performance of the CCLA group compared to all other groups at high element interactivity.

![Graph of mean performance scores for experimental groups.]

*Figure 5.6. Graph of mean performance scores for experimental groups.*

Participants with low maths anxiety using CLT compliant instructional materials (CCLA group) outperformed participants with high maths anxiety (CCHA group), using CLT non-compliant materials (CNLA group), or both (CNHA group). This supported findings for Experiment 1 that indicated both the design of instructional materials and participants’ baseline maths anxiety affected participants’ performance scores. As suggested in Experiment 1, it may be hypothesised that participants’ working memory resources were expended due to anxiety, an inferior instructional design (CLT non-compliant condition), or both, for the other three experimental groups.

### 5.4.3.2 Extraneous Cognitive Load

Research Question 4 investigated whether participants with high baseline mathematics anxiety presented with CLT compliant materials experienced lower extraneous
cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant materials when solving problems of high element interactivity. Participants’ ratings of cognitive load were measured using two scales. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992). Participants’ subjective rating of extraneous cognitive load was measured using items 4-6 from the Cognitive Load Differentiating Scale (CLDS) (Leppink et al., 2013). The results for both subjective cognitive load scales are presented below.

5.4.3.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992).

For Research Question 4, data related to participants’ mental effort ratings were analysed based on participants’ baseline mathematics anxiety. Descriptive results for the four experimental groups are presented in Table 5.9.

Table 5.9
Descriptive Statistics – Mental Effort Rating (CLSRS) with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>CCL A n = 45 Mean (SD)</th>
<th>CCHA n = 51 Mean (SD)</th>
<th>CNLA n = 51 Mean (SD)</th>
<th>CNHA n = 48 Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2.20 (0.99)</td>
<td>3.65 (1.76)</td>
<td>2.16 (1.33)</td>
<td>3.25 (1.68)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.27 (1.67)</td>
<td>5.22 (1.98)</td>
<td>3.34 (1.43)</td>
<td>4.56 (2.18)</td>
</tr>
<tr>
<td>High</td>
<td>4.32 (1.74)</td>
<td>6.22 (2.16)</td>
<td>4.55 (2.00)</td>
<td>5.73 (1.92)</td>
</tr>
<tr>
<td>Total</td>
<td>9.79 (3.91)</td>
<td>15.08 (5.43)</td>
<td>10.05 (4.13)</td>
<td>13.54 (5.18)</td>
</tr>
</tbody>
</table>

Analysis using a one-way ANOVA showed that the experimental group did not have a significant effect on participants mental effort ratings at high element interactivity, $F(3,191) = .662, p = .576$. The results showed that participants with high baseline mathematics anxiety reported higher mental effort when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials compared to participants with high baseline mathematics anxiety using CLT non-compliant instructional materials. These results show that the CLT compliant high baseline mathematics anxiety group (CCHA) reported higher mean mental effort ratings.
than the CLT non-compliant high baseline mathematics anxiety group (CNHA) for tasks of high element interactivity. However, this difference was not significant, $F(1,97) = 1.40, p = .240$.

![Figure 5.7. Graph of mental effort ratings for experimental groups.]

Figure 5.7 shows, as for Experiment 1, the CLT non-compliant high anxiety group (CNHA) reported a greater change in mental effort ratings from moderate element interactivity compared to high element interactivity than the CCHA group. This increase was significant for the CNHA group, $F(1,94) = 7.729, p = .006$ with a medium effect size ($d = .57$). However, unlike Experiment 1, the change in mental effort ratings for the CCHA group when completing tasks of moderate compared to high element interactivity was also significant, $F(1,100) = 5.941, p = .017$ but with a small effect size ($d = .48$). This indicated the increase in element interactivity had greater importance when using CLT non-compliant materials compared to CLT compliant materials. Therefore, similar to Experiment 1, the use of CLT compliant materials became important at high levels of element interactivity and may have had a beneficial effect for highly anxious learners when solving complex tasks.
5.4.3.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

For Research Question 4, data related to participants’ extraneous cognitive load ratings were analysed based on participants’ baseline mathematics anxiety. Descriptive statistics for the four experimental groups are presented in Table 5.10.

Table 5.10

Descriptive Statistics – Extraneous Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA ( n = 45 )</td>
</tr>
<tr>
<td>Interactivity (EI)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.22 (3.27)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.73 (3.76)</td>
</tr>
<tr>
<td>High</td>
<td>3.33 (5.42)</td>
</tr>
<tr>
<td>Total</td>
<td>8.29 (10.69)</td>
</tr>
</tbody>
</table>

Table 5.10 shows mean ECL ratings for groups incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions for tasks of low, moderate and high element interactivity. For both instructional conditions, highly anxious participants reported the greater total extraneous cognitive load compared to low anxious participants. Results of the one-way ANOVA showed the experimental group had a significant effect on participants’ total ECL rating \( F(3,191) = 8.261, p < .001 \).
Figure 5.8 shows for the CCHA group, participants reported the highest ECL rating at all levels of element interactivity compared to all other groups. The CCHA group reported higher mean ECL ratings than the CLT non-compliant high anxiety group (CNHA) at high element interactivity. This difference was significant, \( F(1,97) = 5.062, p = .027 \).

Participants’ subjective ratings of cognitive load were higher at higher levels of element interactivity. At all levels of element interactivity, highly anxious participants reported higher ratings of ECL. Results using the CLSRS showed that CLT compliant materials did reduce the effect of high anxiety on mental effort ratings compared to CLT non-compliant materials, at high levels of element interactivity. The combination of high anxiety and CLT compliant instructions significantly increased participants’ reported extraneous cognitive load when compared to either condition in isolation. The extraneous cognitive load was highest for highly anxious individuals and was exacerbated when using CLT compliant instructional materials solving problems of high element interactivity. As for Experiment 1, results showed that the CLT compliant materials did not reduce the extraneous cognitive load experienced by highly anxious learners. Thus, Hypothesis 5, participants with high baseline maths anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant
instructional materials when solving mathematics problems of high element interactivity, was not supported.

5.4.3.2.3 Additional Findings for Mental Effort and ECL

Additional analysis was conducted to investigate the relationship between mental effort and participants’ reported task difficulty, and instructional efficiency. Because Hypothesis 5 was not supported, additional analysis related to cognitive load and expertise, such as that conducted in Experiment 1, was not undertaken for Experiment 2. Mental effort ratings ascertained from the CLSRS were used in conjunction with performance scores to calculate instructional efficiency. As for Experiment 1, efficiency scores did not indicate any significant instructional advantage for highly anxious participants using CLT compliant materials, most likely as a consequence of non-significant findings between the instructional design conditions. These findings for instructional efficiency can be found in Appendix P (Table P4).

Of particular interest were findings related to participants’ ratings of task difficulty. Descriptive Statistics for Task Difficulty can be found in Appendix P (Table P5). Variations in mental effort ratings associated with element interactivity and participant anxiety may have been affected by participants’ appraisal of task difficulty. A significant positive correlation was found between participants’ reported mental effort and participants’ rating of task difficulty ($r = 0.914$, $n = 585$, $p < .001$). There was a significant positive correlation between element interactivity and task difficulty ratings, $r = 0.376$, $n = 585$, $p < .001$. For participants with high baseline maths anxiety, task difficulty ratings were significantly higher at high element interactivity compared to low element interactivity in both the CLT compliant condition ($F(1,100) = 35.871$, $p < .001$) and the CLT non-compliant condition ($F(1,94) = 22.536$, $p < .001$).

To further investigate the effect of high anxiety on participants’ perception of task difficulty, t-tests were performed to compare ratings of task difficulty for low anxiety participants and high anxiety participants in both the CLT compliant condition and CLT non-compliant condition. Results are presented in Table 5.11.
Table 5.11

*T-Tests For Task Difficulty For Each Group*

<table>
<thead>
<tr>
<th></th>
<th>CCLA V CCHA</th>
<th>CNLA V CNHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Element Interactivity</td>
<td>$t(94) = 3.234, p = .002$</td>
<td>$t(97) = 4.267, p &lt; .001$</td>
</tr>
<tr>
<td>Moderate Element Interactivity</td>
<td>$t(94) = 4.211, p &lt; .001$</td>
<td>$t(97) = 3.559, p = .001$</td>
</tr>
<tr>
<td>High Element Interactivity</td>
<td>$t(94) = 4.035, p &lt; .001$</td>
<td>$t(97) = 3.337, p = .001$</td>
</tr>
</tbody>
</table>

Table 5.11 shows task difficulty ratings were significantly higher for participants with high baseline maths anxiety compared to low baseline anxiety at all levels of element interactivity, in both the CLT compliant condition and the CLT non-compliant condition. Participants with high baseline maths anxiety did not report lower ratings of task difficulty when using CLT compliant instructional materials compared to CLT non-compliant materials, $F(1,97) = 0.694, p = .407$.

**5.4.3.3 Intrinsic and Germane Cognitive Load**

For Exploratory Question 1, data for participants’ subjective ratings of intrinsic cognitive load and germaine cognitive load were analysed according to participants’ baseline mathematics anxiety and participants’ instructional condition. This was done in order to investigate the impact of high baseline mathematics anxiety on ICL and GCL when presented with CLT compliant instructional materials compared to CLT non-compliant instructional materials when solving maths problems of high element interactivity. These ratings were measured using the CLDS.

**5.4.3.3.1 Intrinsic Cognitive Load**

Descriptive statistics for the subjective ratings of ICL for the four experimental groups are presented in Table 5.12.
Table 5.12

Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 45</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>3.09 (3.36)</td>
</tr>
<tr>
<td>Moderate</td>
<td>5.80 (5.85)</td>
</tr>
<tr>
<td>High</td>
<td>8.42 (6.66)</td>
</tr>
<tr>
<td>Total</td>
<td>17.31 (14.31)</td>
</tr>
</tbody>
</table>

Table 5.12 shows data for ICL incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions at low, moderate and high element interactivity. Results of the one-way ANOVA showed the experimental group had a significant effect on ICL ratings at high element interactivity, $F(3,191) = 13.460, p < .001$. However, there was no significant difference between the ICL ratings of the CCHA group and the CNHA group, $F(1,97) = 3.124, p = .080$. Table 5.12 shows ICL ratings were higher for high anxiety participants compared to low anxiety participants in both the CLT compliant condition and the CLT non-compliant condition. The higher ICL for high anxiety participants was evident at all levels of element interactivity. Given this result had been replicated from Experiment 1, analyses using t-tests were conducted to further investigate the effect of anxiety on participants’ perceived ICL in each condition. Results from t-test analyses are presented in Table 5.13.

Table 5.13

T-Tests Showing Significant Difference in ICL For Low and High Anxiety Groups in Each Instructional Design Condition

<table>
<thead>
<tr>
<th></th>
<th>CCLA V CCHA</th>
<th>CNLA V CNHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Element Interactivity</td>
<td>$t(94) = 4.398, p &lt; .001$</td>
<td>$t(97) = 2.840, p = .005$</td>
</tr>
<tr>
<td>Moderate Element Interactivity</td>
<td>$t(94) = 4.451, p &lt; .001$</td>
<td>$t(97) = 3.387, p = .001$</td>
</tr>
<tr>
<td>High Element Interactivity</td>
<td>$t(94) = 5.084, p &lt; .001$</td>
<td>$t(97) = 3.009, p = .003$</td>
</tr>
<tr>
<td>Total</td>
<td>$t(94) = 5.13, p &lt; .001$</td>
<td>$t(97) = 3.49, p = .001$</td>
</tr>
</tbody>
</table>
As shown in Table 5.13, the reported ICL was significantly higher for high anxiety participants compared to low anxiety participants when using both CLT compliant instructions and CLT non-compliant instructions at all levels of element interactivity.

5.4.3.3.2 Germane Cognitive Load

Descriptive statistics for the subjective ratings of GCL for the four experimental groups are presented in Table 5.14.

Table 5.14

Descriptive Statistics – Germane Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 45</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>11.11 (10.94)</td>
</tr>
<tr>
<td>Moderate</td>
<td>12.02 (11.44)</td>
</tr>
<tr>
<td>High</td>
<td>12.71 (10.52)</td>
</tr>
<tr>
<td>Total</td>
<td>35.84 (31.51)</td>
</tr>
</tbody>
</table>

Table 5.14 shows for the CLT compliant condition, participants with low and high anxiety reported similar ratings of germane cognitive load. However, in the CLT non-compliant condition, high anxiety participants reported higher germane cognitive load ratings than low anxiety participants at all levels of element interactivity. Results from the one-way ANOVA for GCL ratings indicated a significant main effect for GCL between the four experimental groups, $F(3,191) = 5.410, p = .001$.

A key finding here was the significantly lower levels of GCL for the CLT non-compliant low anxiety group at all levels of element interactivity in comparison to all other groups. This was consistent with findings from Experiment 1, as shown in Figure 5.9.
Given this result had been replicated from Experiment 1, further analyses using T-tests were performed to investigate the effect on low anxiety and CLT non-compliant materials on participants investment of germane resources. These results confirmed the investment of germane resources was significantly lower for the CNLA group compared to the CNHA group and for the CNLA group compared to the CCLA group (see Table 5.15).

Table 5.15

<table>
<thead>
<tr>
<th></th>
<th>CNLA</th>
<th>CNHA</th>
<th>CCLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Element Interactivity</td>
<td>$t(97) = 3.350, p = .001$</td>
<td>$t(94) = 2.870, p = .005$</td>
<td></td>
</tr>
<tr>
<td>Moderate Element Interactivity</td>
<td>$t(97) = 3.009, p = .003$</td>
<td>$t(94) = 2.655, p = .009$</td>
<td></td>
</tr>
<tr>
<td>High Element Interactivity</td>
<td>$t(97) = 3.581, p = .001$</td>
<td>$t(94) = 3.413, p = .001$</td>
<td></td>
</tr>
</tbody>
</table>

Therefore, participants were less likely to invest cognitive resources in a task of any level of element interactivity if they had low baseline maths anxiety and were using CLT non-compliant materials. This may be as simple as there not being a need to do so, however, their performance scores did not demonstrate superior performance compared
to the CLT compliant low anxiety group. Interestingly, in addition to the GCL rating for the CNLA group being significantly lower than the GCL rating of the CNHA group and CCLA group, the mean GCL rating for this group was lower when completing tasks of high element interactivity compared to the mean GCL rating when completing tasks of moderate element interactivity. That is, as the complexity of the task increased, the investment of germane resources by this group was reduced, a counterproductive response to the increased complexity of the task. However, this decline was not significant, $F(1,100) = 0.051, p = .822$. For all other groups, higher levels of element interactivity resulted in concomitant increases in participants’ ratings of GCL. Additional analysis showed a significant positive correlation between participants’ ratings of task importance and the investment of germane resources, $r = .426, n = 251, p < .001$. The same significant, positive correlation was found in Experiment 1. For tasks of high element interactivity, participants with high baseline maths anxiety reported higher ratings of task importance compared to participants with low baseline maths anxiety. This difference was significant when using CLT non-compliant materials, $t(97) = 2.248, p = .027$. Furthermore, for tasks of high element interactivity, participants with high baseline maths anxiety reported lower ratings of task satisfaction compared to participants with low baseline maths anxiety. This was difference was significant when using CLT compliant materials, $t(94) = 4.011, p < .001$. Therefore, high anxiety had the overall effect of increasing participants’ rating of importance but reducing the level of satisfaction associated with a task of high element interactivity. Descriptive statistics relevant to these additional findings for task importance and task satisfaction can be found in Appendix P (Table P6).

For maths tasks of high element interactivity, there was no significant difference in GCL ratings between the CLT compliant high anxiety group (CCHA) and CLT non-compliant high anxiety group (CNHA), $F(1,97) = 0.016, p = .890$. Thus, highly anxious participants reported similar germane cognitive load (GCL ratings) when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials and CLT non-compliant instructional materials.
### 5.4.3.4 Perceived Task Anxiety Ratings

For Exploratory Question 2, data for participants’ perceived task anxiety were analysed according to participants’ baseline mathematics anxiety and participants’ instructional condition. This was done in order to investigate whether learners with high baseline mathematics anxiety presented with CLT compliant instructional materials reported lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials when solving maths problems of high element interactivity. Descriptive statistics for the perceived task anxiety ratings of the four groups are presented in Table 5.16.

Table 5.16

<table>
<thead>
<tr>
<th>Element Interactivity (EI)</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 45</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.02 (1.06)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.67 (1.62)</td>
</tr>
<tr>
<td>High</td>
<td>3.18 (1.68)</td>
</tr>
<tr>
<td>Total</td>
<td>7.87 (3.83)</td>
</tr>
</tbody>
</table>

Table 5.16 shows participants’ ratings of perceived task anxiety were higher at higher levels of element interactivity for all groups. This was confirmed with analysis using Pearson’s Coefficient which showed a significant positive correlation between the level of anxiety experienced whilst completing the task and both element interactivity ($r = .237$, $n = 585$, $p < .001$), and task difficulty ($r = .848$, $n = 251$, $p < .001$). The experimental group had a significant effect on the overall perceived task anxiety ratings, $F(3,191) = 11.914$, $p < .001$. The CLT non-compliant low anxiety group (CNLA) had the lowest perceived task anxiety at all levels of element interactivity, compared to all other groups.
Figure 5.10 shows perceived task anxiety ratings were higher for participants with high baseline maths anxiety compared to those with low baseline maths anxiety at all levels of element interactivity. At high element interactivity, perceived task anxiety was significantly higher for the CLT compliant high anxiety group (CCHA) compared to the CLT compliant low anxiety group (CCLA), \( t(94) = 5.610, p < .001 \), and also for the CLT non-compliant high anxiety group (CNHA) compared to the CLT non-compliant low anxiety group (CNLA), \( t(97) = 4.838, p < .001 \). Therefore, perceived task anxiety ratings were higher for high anxiety participants than for low anxiety participants when using both CLT compliant and CLT non-compliant materials. However, this may have been due, at least in part, to the higher baseline maths anxiety of these groups. For participants with high baseline anxiety, the perceived task anxiety ratings were higher for those using CLT compliant materials (CCHA) compared to those using CLT non-compliant materials (CNHA). However, this difference was not significant, \( F(1,97) = 0.628, p = .430 \).

5.4.3.4.1 Additional Findings – Perceived task Anxiety and Expertise

As for Experiment 1, the relationship between expertise and perceived task anxiety was investigated. It is important to note that the level of element interactivity relevant to a task is dependent on a learner’s domain specific expertise, and these findings
established that complex tasks incurred greater perceived task anxiety ratings than simple tasks (see Section 5.4.3.4). Descriptive statistics for perceived task anxiety ratings of experts and novices can be found in Appendix P (Table P7).

When data were analysed further considering participants’ level of expertise, the level of expertise was found to have a significant effect on perceived task anxiety ratings. Calculation of Pearson’s coefficient showed a significant negative correlation between expertise and anxiety. As participants’ expertise increased, their level of perceived task anxiety decreased for tasks of low ($r = -0.624$, $n = 82$, $p < .001$), moderate ($r = -0.650$, $n = 82$, $p < .001$) and high ($r = -0.699$, $n = 82$, $p < .001$) element interactivity. Furthermore, the perceived task anxiety reported was greater for novices compared to experts in both instructional conditions. There was a significant difference in the level of perceived task anxiety between experts and novices in both the CLT compliant and CLT non-compliant conditions for tasks of low ($F(1,185) = 5.523$, $p = .020$), moderate ($F(1,185) = 8.364$, $p = .004$) and high ($F(1,185) = 12.817$, $p < .001$) element interactivity. There was no significant difference between the instructional conditions, suggesting CLT compliant materials did not effectively reduce perceived task anxiety for novices or experts. Therefore, in order to ensure anxiety is not evident in maths teaching practice, established levels of expertise might be required.

5.5 DISCUSSION

The overall purpose of this experiment, as for Experiment 1, was to investigate whether CLT compliant instructional materials, that is, worked examples, could support learners with high mathematics anxiety to solve complex algebra problems. Experiment 2 was conducted in a tertiary education setting rather than a secondary education setting as teacher anxiety is thought to influence student anxiety (Beilock et al., 2010; Brown et al., 2008). The experiment involved participants with low or high baseline maths anxiety solving maths tasks of low, moderate and high element interactivity using either CLT compliant materials or CLT non-compliant materials. This experiment also attempted to address limitations identified in Experiment 1, by using a larger sample size and stratified distribution of participants between conditions in order to ensure homogenous grouping of participants in terms of baseline maths anxiety. As in
Experiment 1, rather than attempt to distract learners in order to alleviate anxiety, this research investigated instructional techniques that accommodated elevated anxiety levels in learners, by reducing the cognitive load associated with maths tasks, so that anxiety did not adversely affect the performance of highly anxious students. The interaction between anxiety, cognitive load and instructional design has not previously been investigated and this research proposes a novel approach to providing learning support for anxious maths students. Experiment 2 may also provide additional insight into accommodating anxious learners by investigating anxiety levels that may be affecting their teachers.

The main emphasis for this experiment was fourfold. Firstly, as for Experiment 1, it was necessary to confirm previous research that has shown that learners perform better and report lower cognitive load for tasks of high element interactivity when presented with instructional materials designed in accordance with the principles of cognitive load theory (CLT) than when presented with instructional materials not designed in accordance with CLT principles. Secondly, learner anxiety and cognitive load were investigated to confirm the relationship between these two measures established in Experiment 1. This experiment then examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element interactivity by improving performance scores and reducing cognitive load. Finally, Experiment 2 examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element interactivity by reducing perceived task anxiety when solving maths problems with high element interactivity.

Four research questions and two exploratory questions guided this investigation on the assertion that CLT compliant materials would support highly anxious students and thus result in improved performance and lower extraneous cognitive load. This section will address each research question and the main findings will be discussed in the context of other research.
5.5.1 Performance and Cognitive Load across Instructional Conditions

The first research question was: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

Firstly, it was expected that when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 1). Performance scores were significantly lower for tasks of high element interactivity compared to tasks of low element interactivity, consistent with previous research findings in both the CLT compliant condition and the CLT non-compliant condition (Sweller, 1994). However, the findings showed that there was no significant difference in the performance scores of participants provided with CLT compliant instructional materials compared to participants provided with CLT non-compliant materials (refer to section 5.4.1.1). Thus, Hypothesis 1 was not supported.

Secondly, it was expected when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 2). Participants reported significantly higher cognitive load ratings for tasks of high element interactivity compared to tasks of low element interactivity in both the CLT compliant condition and the CLT non-compliant condition. However, the findings showed that the cognitive load ratings of participants provided with CLT compliant materials were not significantly lower than the cognitive load ratings of participants provided with CLT non-compliant materials (refer to section 5.4.1.2). These findings were consistent for both mental effort ratings (Paas, 1992) and extraneous cognitive load ratings (Leppink et al., 2013). Moreover, for tasks of high element interactivity, ECL ratings attained using the CLDS
(Leppink et al., 2013) were significantly higher for the CLT compliant condition compared to the CLT non-compliant condition. This may suggest a redundancy effect related to CLT compliant materials for participants in the CLT compliant condition. Thus, Hypothesis 2 was not supported.

5.5.2 Cognitive Load and Baseline Mathematics Anxiety

Research Question 2 was: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?

It was predicted that participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher load imposed on working memory caused by anxiety (Hypothesis 3). At low, moderate and high element interactivity, there was a significant positive correlation between participants’ baseline maths anxiety and subjective ratings of mental effort using the CLSRS (Paas, 1992), and ICL and ECL using the CLDS (Leppink et al., 2013) (refer to Table 5.6). These results confirmed Hypothesis 3 and thus corroborated the relationship between anxiety and cognitive load established in Experiment 1.

Anxiety clearly places a burden on working memory and is therefore an important factor in CLT research. Further analysis of data in Experiment 2 (see Table 5.7) suggests that high baseline maths anxiety levels brought about:

1. Higher ratings of mental effort, which were also higher at higher levels of element interactivity for all experimental groups. The increase in mental effort was associated with the increase in the complexity of the task. Participants with high maths anxiety reported significantly higher effort ratings which were not alleviated by using CLT compliant materials perhaps due to the load associated with processing the worked examples or due to the expertise of the participants (not requiring the worked examples);
2. Higher reported ICL, which was also higher at higher levels of element interactivity for all groups. This was indicative of the increased complexity at higher element interactivity. ICL is traditionally considered to be determined solely by the level of element interactivity and was not expected to be influenced by other factors. However, these results suggest anxiety may influence a participant’s perception of the intrinsic load associated with a complex task. However, these results also suggested anxiety and CLT compliant materials contributed to a greater perceived ICL, perhaps due to worked examples presented suggesting tasks were of greater complexity for highly anxious participants;

3. Higher reported ECL, which was also higher at higher levels of element interactivity for all groups. At high element interactivity, ECL was significantly higher for highly anxious participants using CLT compliant materials (CCHA group) compared to the low anxious CLT compliant group (CCLA) and the high anxious CLT non-compliant group (CNHA). The use of CLT compliant materials compared to CLT non-compliant materials did not reduce ECL for highly anxious individuals. This was consistent with findings in Experiment 1 (see Section 4.5.2) and was investigated further in Part 3.

5.5.3 Problem Solving Performance

The third research question was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems of high element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) would outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) on performance scores, due to the reduction of extraneous cognitive load and greater investment of germane resources afforded by CLT compliant instructional
materials (Hypothesis 4). These findings showed that highly anxious learners did not achieve significantly higher performance scores while using CLT compliant instructional materials compared to highly anxious learners using CLT non-compliant instructional materials when solving complex (high element interactivity) mathematics problems (refer to Table 5.8). Thus Hypothesis 4 was not supported. High anxiety had a negative effect on the performance scores of participants using both CLT compliant and CLT non-compliant materials. CLT compliant instructions did not improve the performance of highly anxious learners when completing complex problems.

Anxiety had a detrimental effect on performance, and performance scores were lower at higher levels of element interactivity for all groups. Both high anxiety and high element interactivity were obstructive factors in terms of performance as they consumed working memory resources.

Participants identified as low baseline maths anxiety outperformed those with high baseline maths anxiety when using both CLT compliant instructional materials and CLT non-compliant materials. Interestingly, as in Experiment 1, the CCLA group performed significantly better than all other groups when completing maths tasks of high element interactivity (refer to section 5.4.3.1.1). At high levels of element interactivity, the use of CLT compliant materials significantly improved performance scores for participants with low baseline anxiety, but not for participants with high anxiety. The use of CLT non-compliant instructional materials (CCLA compared to CNLA), high anxiety (CCLA compared to CCHA), or both (CCLA compared to CNHA), was detrimental to the performance scores of participants, as indicated by significant differences between these groups.

5.5.4 Extraneous Cognitive Load

Cognitive load was measured using scales based on the Cognitive Load Subjective Rating Scale (Paas, 1992) for mental effort ratings, and the recently developed instrument for measuring different types of cognitive load (Leppink et al., 2013) for ratings of extraneous cognitive load. Similar to Experiment 1, results for cognitive load ratings have been presented and explained based on both of these scales. Research
question 4 was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower extraneous cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials would report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials (Hypothesis 5).

Overall, an increase in element interactivity generated a corresponding increase in mental effort ratings for all groups (refer to Table 5.9), which was expected given the increased complexity of the task. In addition, participants with high baseline maths anxiety reported greater mental effort when using both CLT compliant and CLT non-compliant materials. Participants with high maths anxiety using CLT compliant materials (CCHA group) reported the highest mental effort when solving maths problems of both low and high element interactivity. However, these differences were not significant. Interestingly, as in Experiment 1 (refer to Section 4.5.4), the increase in mental effort reported at high element interactivity compared to moderate element interactivity was less for the CCHA group (significant but not important) compared to the CNHA (significant and important) (refer to Figure 5.7). Despite the mental effort ratings of the CCHA group not being significantly lower than the CNHA group at high element interactivity, this result suggests that CLT compliant materials may have provided some support for highly anxious learners for tasks of high levels of element interactivity.

Furthermore, an increase in the level of element interactivity resulted in a concomitant increase in ECL (refer to Table 5.10). The CCHA group reported the highest ECL at all levels of element interactivity compared to all other groups, with ECL ratings for this group being significantly higher than all other groups when solving maths problems of
high element interactivity. These results for ECL ratings were consistent with findings from Experiment 1 and again suggest that anxiety or CLT compliant materials alone did not affect ECL ratings, unlike a combination of these two variables that brought about significantly higher ECL ratings.

However, unlike Experiment 1, there was a significant difference between the reported ECL for highly anxious participants using CLT compliant materials compared to those using CLT non-compliant materials. CLT compliant materials may have increased the burden on working memory for highly anxious participants and seen as ‘more’ information rather than providing assistance, and as a result, may have exacerbated the level of anxiety experienced. Alternatively, this could be attributed to the level of expertise of the participants using worked examples provided which imposed unnecessary additional processing of the task. For students already competent in this area of algebra, the provision of worked examples may have in fact added to the level of cognitive load. This effect would support previous research that suggests the use of worked examples to be beneficial only in the early stages of learning and less effective, potentially detrimental, at later stages of learning (Kalyuga, 2007; van Merriënboer, 1997). This effect was the result of cognitive resources being allocated to instructional materials not required by the learner to perform the task successfully, known as redundancy. Alternatively, there is no surety associated with whether the students actually studied and made effective use of the worked examples under the CLT compliant conditions. In addition, the possibility that students have not been sufficiently trained in the use of worked examples may have impacted the reported load. Previous research indicates that performance may be negatively affected by a lack of understanding of the purpose and correct use of worked examples (Schwonke, Renkl, Krieg, Wittwer, Alven, & Salden, 2009). The provision of worked examples may have created additional processing requirements and were therefore seen as requiring more work and creating greater load, particularly for highly anxious learners. For participants with high maths anxiety, the use of CLT compliant materials did not support learning any more than the use of CLT non-compliant materials.

These findings indicated there were no significant differences for subjective mental effort ratings or subjective ratings of ECL of highly anxious learners when using CLT
compliant materials compared to CLT non-compliant materials. Thus, Hypothesis 5 was not supported. This does not support previous research that suggests the use of worked examples reduces the ECL of a task (Paas et al., 2003b).

Despite Hypothesis 5 not being confirmed, the following interesting results surfaced when findings related to low anxious participants and task difficulty were investigated (refer to Section 5.4.3.2.3).

Similarly to Experiment 1, participants in the CCLA group reported the lowest mental effort compared to all other groups, suggesting low anxiety and CLT compliant instructions variables the best combination for reducing mental effort associated with a task. Collectively, CLT compliant materials and low baseline maths anxiety significantly reduced cognitive load, due to the absence of additional cognitive load associated with anxiety or poorly designed instructional materials.

Secondly, participants’ ratings of task difficulty followed the same pattern as mental effort: high anxiety resulted in a concomitant increase in the perceived difficulty of a task when using both CLT compliant materials and CLT non-compliant materials. However, CLT compliant materials did not significantly reduce task difficulty for highly anxious participants. Participants with high baseline maths anxiety reported higher perceived difficulty ratings than participants with low baseline maths anxiety.

Ratings of task difficulty were also higher at higher levels of element interactivity for all groups. The increased difficulty was associated with the increased complexity of the task. CLT compliant materials did not provide learning support for high anxiety participants.

5.5.5 Intrinsic and Germane Cognitive Load

Exploratory question 1 was: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials? Measurement of the individual components of cognitive load using the
CLDS (Leppink et al., 2013) allowed an investigation into any effects anxiety might have had on ICL and GCL when solving complex tasks.

Intrinsic Cognitive Load

This research investigated whether high anxiety impacted participants’ subjective rating of ICL, and also whether this differed with the use of CLT compliant materials compared to CLT non-compliant materials. These findings suggest high anxiety impacted the intrinsic cognitive load of tasks of all levels of element interactivity when using both CLT compliant materials and CLT non-compliant materials. As expected, there was no significant difference between the ICL ratings of participants using CLT compliant materials and CLT non-compliant materials. The intrinsic cognitive load refers to the load associated with the complexity of the task and is independent of instructional design (Sweller, 2010). For all experimental groups, subjective ratings of ICL were higher at higher levels of element interactivity. This indicated the tasks were appropriately categorized as low, moderate and high element interactivity, with high ICL ratings corresponding to high levels of element interactivity (Sweller, 1994). High baseline maths anxiety resulted in significantly higher ICL ratings for participants in both CLT compliant and CLT non-compliant instructional conditions. The CCHA group reported the highest ICL overall. However, the difference in ICL ratings between the CCHA group and CNHA group was not significant for tasks of high element interactivity (refer to Section 5.4.3.3.1). Thus, these findings suggest that participants with high anxiety perceived the intrinsic cognitive load of a complex task to be higher than did participants with low anxiety. However, results did not suggest a difference in ICL exists between high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials when solving problems of high element interactivity. Results for ICL ratings concur with findings from Experiment 1.

Germaine Cognitive Load

This research investigated whether high anxiety impacted participants’ subjective rating of GCL, and also if this differed with the use of CLT compliant materials compared to CLT non-compliant materials. Overall, these findings suggest high anxiety impacted the germane cognitive load of tasks of all levels of element interactivity when using CLT
non-compliant materials. These findings showed that participants using CLT compliant instructional materials reported significantly higher GCL by compared to participants using CLT non-compliant instructional materials at all levels of element interactivity (refer to Figure 5.5). For all participants, higher levels of element interactivity resulted in greater investment of germane resources to accommodate the increased complexity of the task (refer to Table 5.14). However, findings for Experiment 2 do not suggest a distinct advantage for the CCHA group with regards to germane load, as they did in Experiment 1. All groups reported similar GCL ratings at all levels of element interactivity except for the CNLA group, which reported significantly lower GCL ratings at all levels of element interactivity. As for Experiment 1, low anxious participants using CLT non-compliant materials (CNLA) reported the lowest GCL ratings at all levels of element interactivity. In addition, the CNLA group was the only group to invest less germane resources for tasks of high element interactivity compared to tasks of moderate element interactivity. This suggested the CLT non-compliant materials did not provide enough learning support for these participants, or alternatively, these participants were not as motivated to invest germane resources, as indicated by lower ratings of task importance. Overall, these findings suggest participants using CLT compliant materials reported similar GCL ratings regardless of their baseline maths anxiety. These GCL ratings were also similar to high anxiety participants using CLT non-compliant materials; the reported GCL ratings being significantly lower for the CNLA group. As for Experiment 1, findings showed no significant difference in germane cognitive load (GCL ratings) for highly anxious learners when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials and CLT non-compliant instructional materials.

Similar to Experiment 1, there was a significant correlation between participants’ ratings of GCL and task importance. (refer to Section 5.4.3.3.2). High baseline maths anxiety resulted in greater importance being placed on each task but reduced participants’ satisfaction with a complex task. A participant’s level of satisfaction was improved with the use of CLT compliant materials only when their baseline level of maths anxiety was low. Participants using CLT compliant materials reported higher ratings of task importance, suggesting the provision of CLT instructional materials
encouraged participants to consider the task being completed as more important than when provided with CLT non-compliant materials. If participants did not consider a task to be important, the investment of germane resources into that task would be unlikely. Similarly, if learners were satisfied with their performance, the incentive to invest additional resources would be reduced. These participants may have perceived a satisfactory performance, as they did not have worked examples accompanying their materials to compare their own responses, hence providing less feedback regarding their performance. In addition, if a task was believed to be of greater importance, this may have resulted in additional processing and may also have created additional anxiety.

5.5.6 Perceived task Anxiety Ratings

Exploratory question 2 was: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

This research examined whether participants with high maths anxiety that used CLT compliant instructional materials (CCHA group) reported lower perceived task anxiety than participants with high maths anxiety that used CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity. There was no significant difference in perceived task anxiety ratings between the CCHA group and the CNHA group at high element interactivity. As for Experiment 1, these findings showed tasks of higher levels of element interactivity resulted in corresponding higher levels of task anxiety (refer to Table 5.16). Participants with high baseline maths anxiety reported significantly higher perceived task anxiety ratings when using both CLT compliant materials and CLT non-compliant materials. The increased perceived task anxiety could be attributed to the baseline maths anxiety of the participant as well as the difficulty of the task (results show a significant positive correlation between difficulty and perceived task anxiety).

As in experiment 1, high anxiety was not alleviated by the learning support associated with the use of CLT compliant instructional materials. There are a number of possible
reasons why CLT compliant materials were not able to more successfully alleviate anxiety experienced by highly anxious maths participants. The use of CLT compliant instructional materials may have created more work for highly anxious participants due to perceived testing contributing to participants’ anxiety (test anxiety is a separate and confounding source of anxiety). Alternatively, participants may not have been familiar with effective use of worked examples and CLT compliant materials may have increased the perceived difficulty of a task (if the task requires support materials, it must be difficult). It is possible that the additional importance placed on a task as a result of being supplied with worked examples (see Section 5.5.5) may have induced additional anxiety in participants. The worked examples provided may have been overwhelming for highly anxious participants. Also, more processing capacity may have been required to use CLT compliant materials effectively, or students may not have used the worked examples provided. In addition, results indicated that the detrimental effects of anxiety were exacerbated by lack of expertise, with novices reported significantly more perceived task anxiety than experts when solving maths problems of any level of difficulty.

Finally, there was no significant difference between the instructional conditions, suggesting CLT compliant materials did not effectively reduce perceived task anxiety for novices or experts. Furthermore, these findings showed expertise significantly reduced participants’ ratings of perceived task anxiety for tasks of high element interactivity. This suggests development of expertise in the domain of mathematics for highly anxious learners may be an important means of alleviating mathematics anxiety. These findings were consistent with results for Experiment 1.

5.5.7 Summary of Results

As for experiment 1, of the four research questions investigated, only one of the five associated hypotheses was confirmed. Support of hypothesis 3 indicated an association exists between learner anxiety and cognitive load experienced whilst completing a task of high element interactivity, which was suggested in Experiment 1. Results show that both high element interactivity and high learner anxiety had a significant negative impact on performance, all measures of cognitive load and
perceived task anxiety ratings. There was a significant positive correlation between participants’ AMAS score and ratings of mental effort, ICL, ECL, GCL, task difficulty and perceived task anxiety, and a significant negative correlation between participants’ AMAS score and performance score at all levels of element interactivity. These results were consistent with findings for Experiment 1. At high element interactivity, CLT compliant instructional materials supported learning for participants with low maths anxiety only. As in Experiment 1, the CCLA group achieved the highest performance scores and reported the lowest mental effort ratings for tasks of high element interactivity compared to all other groups. For participants with high baseline maths anxiety, CLT compliant materials did not result in improved performance scores or lower mental effort ratings. In addition, high anxiety participants also reported significantly higher ratings of task difficulty when using both CLT compliant instructional materials and CLT non-compliant instructional materials. For high anxiety participants, the use of CLT compliant materials increased ICL (not significantly), increased ECL (significantly) and decreased GCL (not significantly) compared to using CLT non-compliant materials. The higher extraneous cognitive load for the CCHA group was consistent with findings from Experiment 1.

Analysis of participants’ ratings of task satisfaction and task importance revealed students with high baseline maths anxiety reported lower satisfaction and higher importance at all levels of element interactivity. The use of CLT compliant materials increased participants’ satisfaction rating for low anxiety participants only. CLT compliant instructional materials increased the level of importance placed on a task. Interestingly, participants in the CNLA group reported significantly lower importance ratings, which corresponded to the significantly lower GCL reported by this group compared to all other groups.

Finally, the use of CLT compliant instructional materials did not significantly reduce perceived task anxiety ratings of high anxiety participants. However, as in Experiment 1, at high element interactivity, the increase in perceived task anxiety was greater for the CNHA compared to the CCHA group. However, this difference was not significant.
5.6 LIMITATIONS

The main limitation associated with Experiment 1, that the participants in the CLT compliant condition had significantly higher baseline anxiety scores compared to the participants in the CLT non-compliant condition, was not a limitation in Experiment 2. The sample size was larger for Experiment 2 and this allowed for the random allocation of participants into the two instructional conditions to generate homogeneous experimental groups in terms of anxiety. There was no significant difference in the baseline anxiety scores of participants in the CLT compliant condition and the CLT non-compliant condition, and the AMAS scores used to categorise participants as low anxiety or high anxiety were the same in both conditions.

The limitations of this experiment were firstly associated with the design of instructional materials. In Experiments 1 and 2, the CLT non-compliant condition received some product-oriented worked examples on a separate sheet (this sheet was coloured in Experiment 2), which may have provided additional insight and assisted them in the successful completion of the task. Future experiments should ensure that the design of instructional materials more accurately constitute CLT compliant and CLT non-compliant, that is, without provision of worked examples whatsoever. For anxious students, available working memory resources are limited, so CLT compliant materials, which reduce ECL, should be very important in enabling students to perform well, especially when completing tasks with high element interactivity.

In addition, comparison of results for tasks of low, moderate and high element interactivity may not have been distinctive enough in some cases to provide significant effects in analysis. Maths problems in future experiments should be of low and high element interactivity only in order to increase the variation between the tasks completed by the participants. This would also allow the inclusion of additional problems to solve at each level of element interactivity to be completed by participants in the experiment.

As for Experiment 1, a limitation of the study was there was no way of monitoring the extent of participants’ use of the worked examples or in fact whether they were using them effectively. It was assumed participants had been trained in the use of worked
examples in maths, and understood their importance in providing support for a task, but this may not have been the case for all participants. In addition, despite reassurance that the experiment was not a test and did not influence their assessment for the course, there was no way of ascertaining whether students experienced any anxiety due to participation in the study.

A further limiting factor was variation in the level of expertise of participants, as it was for Experiment 1. In a tertiary setting, one would expect considerable variation in ability and prerequisite maths knowledge. Although this information was obtained from participants, their expertise would affect the level of element interactivity of tasks completed in the experiment, and therefore the cognitive load associated with a task. This may also have affected participants’ level of engagement in the study. Engagement in the task may be reduced for both experts (if the task is considered too easy) and novices (if the task is perceived as too difficult).

In summary, upon reflection of Experiments 1 and 2, the following limitations have been identified and will be addressed in Experiment 3:

1. Large sample size or stratified sampling to ensure homogeneous experimental groups in terms of baseline anxiety;
2. More robust conditions in terms of the level of CLT compliance of instructional materials, that is, process oriented worked examples provided in the CLT compliant condition and conventional problems to solve, without provision of worked examples in the CLT non-compliant condition;
3. Problems of low and high element interactivity only;
4. Minimal variation in the level of expertise of participants in order to create more homogeneous group for comparison in analysis.

5.7 CONCLUSION

These results showed that a high level of element interactivity reduced performance scores, increased all measures of cognitive load and increased participants’ perceived task anxiety rating. It is essential, therefore, that when learners are solving complex
tasks, strategies are implemented to simplify these problems. This is especially true for learners with high maths anxiety, whose performance, and experience of cognitive load and perceived task anxiety is exacerbated by their maths anxiety. This experiment found that CLT compliant instructional materials might provide some relief for these learners in certain circumstances. As for Experiment 1, it emerged that a combination of low anxiety and CLT compliant instructional materials (CCLA group) comprised the most favourable conditions for effective learning, that is, highest performance scores with lowest mental effort ratings. However, limitations of the experiment, mainly associated with contrast between instructional materials in the CLT compliant condition and CLT non-compliant condition, have impacted the significance of results in a number of circumstances.

Experiment 3 was undertaken to further investigate findings from Experiments 1 and 2. The methodology from previous experiments was retained, however, changes were made to the instructional materials in order to address limitations associated with these in previous experiments (see Section 5.6). In addition, stratified sampling techniques were used to allocate participants to each condition in order to ensure homogeneous groups in terms of anxiety, and avoid the limitations identified in Experiment 1.
6 EXPERIMENT 3

6.1 INTRODUCTION

The purpose of Experiment 3 was to further investigate whether instructional format consistent with cognitive load theory reduced cognitive load and anxiety experienced by learners when solving mathematics problems by addressing limitations identified in both Experiment 1 and Experiment 2. As in previous experiments, CLT compliant instructional materials involved the use of paired process-oriented worked examples for algebra problems. Participants were secondary school students as for Experiment 1. This was done in order to provide a comparison with findings from Experiment 1 and hopefully provide some insight into secondary students with high maths anxiety. Specifically, Experiment 3 explored whether the use of cognitive load theory compliant materials reduced maths anxiety and associated cognitive load leading to improved performance when mathematics tasks of varying levels of element interactivity were completed. Participants subjective measures of extraneous, intrinsic and germane cognitive load associated with solving the maths problems using either CLT compliant or CLT non-compliant instructional materials for mathematics tasks of both low and high element interactivity were recorded. The provision of worked examples has been found to be of assistance to learners when element interactivity is high as a result of the complexity, and associated load on working memory, of such materials (Leahy & Sweller, 2005). In this experiment, as highly anxious learners have an additional burden on WM, it was thought the worked example effect may be evident when solving mathematics tasks of low element interactivity, so this too was investigated.

Four aims for this experiment were the same as Experiment 1 and 2. Firstly, this experiment aimed to confirm previous research that has shown the provision of instructional materials designed in accordance with cognitive load theory (CLT) assist learners by reducing cognitive load and improving performance scores when completing complex tasks (see Research Question 1). Findings from Experiment 1 and 2 did not confirm these hypotheses so adjustments were made to the instructional materials for this experiment. The instructional materials used in Experiment 3 consisted of more extreme differences in design between the CLT compliant instructional condition and
the CLT non-compliant instructional condition. Firstly, participants in the CLT compliant condition were provided with process oriented worked examples and participants in the CLT non-compliant condition were provided with conventional problems to solve, without any worked examples. Secondly, participants completed tasks of low and high element interactivity only. This design change was undertaken to provide greater differentiation between the conditions in terms of instructional design. Findings from Experiment 1 and 2 provided evidence of a relationship between learner anxiety and cognitive load. Experiment 3 could provide further confirmation of these findings (see Research Question 2). Thirdly, this experiment proposed to examine whether worked examples provided assistance to highly anxious learners by reducing learners cognitive load thereby improving maths performance scores for tasks of high element interactivity (see Research Questions 3 and 4 and Exploratory Question 1). Finally, this experiment investigated whether worked examples assist learners with high maths anxiety when solving maths problems of high element interactivity by reducing perceived task anxiety (see Exploratory Question 2). Furthermore, Experiment 3 also introduced an additional focus to examine if worked examples assisted in reducing learners cognitive load and anxiety and improve maths task performance for tasks of low element interactivity. This allowed an assessment of whether the worked example effect was evident for tasks of low element interactivity in addition to tasks high element interactivity for highly anxious learners, due to additional load associated with anxiety.

The research questions and associated alternative hypotheses being investigated were the same as for Experiment 1 and 2, with the addition of one further Research Question and associated hypothesis. It is important to note here that whist participants in the CLT compliant condition received process-oriented worked examples in their instructional materials (as in Experiment 1 and 2), instructional materials for participants in the CLT non-compliant condition consisted of conventional problem solving tasks only. The research questions and associated alternative hypotheses are as follows:

RQ1: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance
scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

H1: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

H2: When solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials.

RQ2: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?

H3: Participants with high baseline mathematics anxiety will report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety.

RQ3: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H4: When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials on performance scores, due to the
reduction of extraneous cognitive load and greater investment of germane resources afforded by CLT compliant instructional materials.

RQ4: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower extraneous cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H5: When solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials.

RQ5: When solving problems low in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

H6: When solving mathematics problems low in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will achieve higher performance scores and report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. This is due to CLT compliant instructional materials providing learning support when WM resources are expended by anxiety.

The Exploratory Research Questions being investigated was:

EQ1: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety
learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials?

EQ2: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

The following Sections 6.2 and 6.3 provide detail of Methodology and Data Analysis for Experiment 3. Much of these are as for Experiments 1 and 2, with specific differences in participant group, instructional materials, experimental materials, procedure and the composition of high and low anxiety groups explained in relevant sections (6.2.2, 6.2.3, 6.2.4, 6.2.5 and 6.3.1 respectively).

6.2 METHODOLOGY

6.2.1 Research Design

The need for an additional experiment was identified in order to address two main limitations from Experiments 1 and 2. Experiment 1 had participants with significantly higher baseline anxiety scores in the CLT compliant condition, $F(67,1) = 1.047, p = .010$. The baseline mathematics anxiety level (AMAS score) of those participants in the CLT compliant condition ($M = 24.63, SD = 5.58$) was significantly higher than the CLT non-compliant condition ($M = 21.46, SD = 4.31$). That is, by chance, there were more highly anxious students in the CLT compliant condition. Therefore, it was necessary to investigate whether groups with similar baseline measures of anxiety would provide more conclusive answers to the research questions. Experiment 2 comprised a larger sample size than Experiment 1, and as a result, random allocation of participants generated homogeneous experimental groups. In Experiment 3, homogeneous groups in terms of anxiety required this variable to be stratified prior to allocation of participants to CLT compliant and CLT non-compliant conditions.
In addition, previous experiments involved the provision of worked examples in both conditions. Instructional materials in the CLT compliant condition included process-oriented worked examples paired with conventional problems to solve. The CLT non-compliant condition was presented only with conventional problems to solve in their booklets, as well as a separate sheet with a selection of product-oriented worked examples. The provision of these worked examples for participants in the CLT non-compliant condition may have minimised the difference between the two conditions. The product-oriented worked examples, despite creating a split attention effect, may have provided some support for learners, minimising the difference between the two conditions. Furthermore, in Experiment 2, this sheet of worked examples provided was coloured which may have reduced the split attention effect that may otherwise arise by attracting the students’ attention. It was therefore necessary to investigate whether increasing the difference between the two instructional formats would provide more conclusive answers to the research questions. A clear distinction between the two conditions could be achieved by providing paired process-oriented worked examples for participants in the CLT compliant condition and conventional problems to be solved, with no worked examples, in the CLT non-compliant condition.

Research design for Experiment 2 was effectively the same as for Experiments 1 and 2. Differences included the content of the instructional materials and research was conducted in a secondary setting, as for Experiment 1. Overall, the major design changes in Experiment 3 included extending the difference between the instructional materials in terms of the degree of CLT compliance and also ensuring similar distribution of low and high anxiety learners in each condition. In addition to these major changes, comparison between maths problems of low and high element interactivity only was performed in order to maximise the difference between the element interactivity of tasks completed, with the number of each problem type to be completed by participants increased from five to ten for each section. Finally, all students were considered novices in terms of solving algebra problems. This eliminated any influence that expertise might have in the current experiment on the students’ performance, the cognitive load experienced when solving algebra problems and the usefulness of worked examples.
All instruments used in Experiment 3 were otherwise the same as those used in Experiments 1 and 2. Experiment 3 used a between subjects design to examine performance, cognitive load and perceived task anxiety of secondary school students. Participants were required to solve a series of twenty algebra mathematics problems of low or high element interactivity (10 of low element interactivity followed by 10 of high element interactivity). A 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2 (Element Interactivity Condition) factorial experimental design was implemented.

The independent variables in this 3-way factorial design are as follows:

1. Instructional Design Condition: Instructional materials were either CLT compliant or CLT non-compliant (explained below)
2. Baseline maths anxiety: Participants were identified as high mathematics anxiety or low mathematics anxiety based on the Abbreviated Maths Anxiety Scale (see Section 6.3.2)
3. Element interactivity of task (task complexity): Mathematics tasks of low and high element interactivity.

Instructions were either cognitive load theory (CLT) compliant (using worked examples) or cognitive load theory (CLT) non-compliant. CLT compliant instructional materials consisted of paired process-oriented worked examples with key processes in each example highlighted and explained. The worked examples encouraged students to self-explain the procedure as well as provide feedback throughout the process. CLT non-compliant instructional materials had only conventional problems to solve in the instructional booklets and participants were not provided with any additional support. These materials provided a more extreme difference between instructional materials provided in the CLT compliant condition and the CLT non-compliant condition. Algebra problems to be solved were presented in order of increasing difficulty in both conditions. The instructional materials are explained in more detail in Sections 6.2.3 and 6.2.4.

The dependent variables were as follows:

1. Performance on mathematics tasks;
2. Cognitive load / mental effort measured subjectively using two scales:
   (i) Cognitive Load Subjective rating Scale (CLSRS) (Paas, 1992);
   (ii) Cognitive Load Differentiating Scale (CLDS) differentiating between
        intrinsic (ICL), extraneous (ECL) and germane (GCL) cognitive load (Leppink
        et al., 2013);
3. Subjective measure of perceived task anxiety (Baloglu & Zelhardt, 2007);
4. Completion time for algebra tasks in each Section, A and B;
5. Perceived task difficulty, task importance, task engagement and task
   satisfaction. Participants reported subjective ratings of the factors following
   completion of algebra tasks in each Section, A and B.

   These variables were the same as those in Experiment 1; further detail can be found in
   Section 4.2.1.

   **6.2.2 Participants**

   Ninety-two students (48 males and 44 females) from an urban co-educational
   independent school in NSW, Australia, participated in the study. Participants in this
   study were secondary maths students aged 13-14 years studying Stage 4 (Academic
   Years 7 and 8) mathematics (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-
   k10/). All students were currently enrolled in Year 8 Mathematics course. Students
   studying Stage 5 had participated in Experiment 1, resulting in some variation in levels
   of expertise regarding algebra. Students studying Stage 4 were chosen in this study in
   order to create a more homogeneous group by minimising any variation in domain
   specific expertise. No independent testing of students’ mathematical ability was
   conducted. However, Stage 4 students were considered novices in the area of algebraic
   problems solved in this task. Algebra of the standard used in the testing phase is only
   introduced to students at the Stage 4 level and it would not be expected that sufficient
   time had been spent on these tasks to develop expertise in this domain. The content used
   in the experiment could therefore be considered to be of similar difficulty for all
   participants.

   The experiment was conducted in regular class time during weeks 3 and 4 of Term 2 in
   a four term year. The testing occurred over two sessions. The first session (15 minutes)
was for participants to complete the AMAS questionnaire. This provided a baseline measure of anxiety for each participant and was used to randomly allocate equal numbers of low and high maths anxious learners to each instructional design condition. The second session (45 minutes) was for completion of the maths tasks of the experiment by participants, and was conducted a week later. Ethics approval for the experiment was received from the University of Wollongong Human Research Ethics Committee (see Appendix Q).

Prior to conducting the experiment, one face-to-face meeting was held with relevant staff, consisting of Head of Mathematics and Year 8 classroom teachers. This meeting confirmed that the testing materials were of a suitable level of difficulty and were aligned with the students’ ability across the year group. Furthermore, teachers confirmed students were familiar with the use of worked examples as they were regularly incorporated into their classroom instruction. Consent and Participant information sheets were provided for distribution to parents and participants (See Appendices U and V). Staff involved were also provided with information regarding the purpose of the study, the relevance of the research and specific instructions for conducting the experiment (See Appendices W and X).

6.2.3 Instructional Materials

The instructional materials were designed as either CLT compliant or CLT non-compliant. The algebra problems participants were required to solve were different to Experiment 1 and 2 in order to align with the prior knowledge associated with current enrolment in Stage 4 Mathematics. These two instructional design conditions are explained in detail as follows.

**CLT Compliant Condition**

Participants in this condition \( n = 43 \); 25 males, 18 females) were provided with CLT compliant instructional materials consisting of process-oriented worked examples paired with conventional algebra problems to be solved. The key processes in each worked example were highlighted and an explanation of the procedure was written next to each step (as shown in Figure 6.1). The worked examples were incorporated into the
worksheet in order to avoid split-attention effects. The experimental materials are explained in more detail in the next section and the complete set of materials for the CLT compliant condition can be found in Appendix S.

**EXAMPLE**

2. **Solve for** $x \quad 3x + 5 = 20$

\[
\begin{align*}
3x + 5 &= 20 - 5 \\
3x &= 15 \\
3x + 3 &= 15 + 3 \\
x &= 5
\end{align*}
\]

**(subtract 5 from both sides)**

**(divide both sides by 3)**

**QUESTION**

**SOLUTION**

Solve for $y \quad 2y + 1 = 25$

\[2y + 1 = 25\]

\[2y = 24\]

\[y = 12\]

*Figure 6.1. Sample worked example and problem of low element interactivity to solve from CLT compliant instructional materials.*

**CLT non-Compliant Condition**

Participants in this condition ($n = 49$; 23 male, 26 female) were provided with CLT non-compliant instructional materials. Participants were required to solve the same mathematics problems as in Condition 1. However, each problem was presented as a conventional problem to solve, as shown in Figure 6.2. Unlike Experiment 1 and 2, no
support materials were provided to participants in the CLT non-compliant condition in order to maximise the contrast with the instructional materials provided in the CLT compliant condition. Despite the evident split attention associated with the provision of a separate sheet of product-oriented worked examples in the CLT non-compliant condition in Experiments 1 and 2, it was considered to provide assistance to participants in this condition compared to the CLT compliant condition. Complete instructional materials for the CLT non-compliant condition can be found in Appendix T.

Solve for $y$ 

\[ 2y + 1 = 25 \]

Figure 6.2. Sample problem to solve of low element interactivity from CLT non-compliant instructional materials.

The CLT compliant materials contained process-oriented worked examples that were clearly paired with the conventional problem to be solved. This provided participants with direction, as well as minimising any split attention involved in using the worked example. Furthermore, the process-oriented worked example had key features of the solution highlighted in order to provide further assistance to the participant. The CLT non-compliant materials provided no learning support through the inclusion of worked examples. The intention was to create an extreme variation to the CLT compliant condition to which it was being compared.
6.2.4 Experimental Materials

Some adjustments to the structure and content of experimental materials from Experiment 1 and 2 were necessary and the following amendments were made to the experimental materials for Experiment 3:

- More extreme design differences between the two conditions so they more accurately reflect CLT compliant and CLT non-compliant instructional materials (see Section 6.2.3),
- Inclusion of tasks with a level of difficulty consistent with students studying Stage 4 mathematics (Year 8),
- Inclusion of tasks of low and high element interactivity only, with participants completing 10 questions of each. Therefore, Part 2 of the experimental materials consisted of only two sections. This replaced 3 sections for tasks of low, moderate and high element interactivity, each with 5 questions, in previous experiments.

The instructional materials consisted of a total of 20 algebra problems (10 questions of low element interactivity and 10 questions of high element interactivity) that were designed for students working towards completion of Stage 4 Mathematics outcomes from the Patterns and Algebra Strand of the NSW Education Standards Authority Mathematics K-10 Syllabus (http://syllabus.nesa.nsw.edu.au/mathematics/mathematics-k10/). As stated previously, the level of difficulty of the algebra problems was made in consultation with the students’ classroom teachers to ensure pre-requisite algebra content had been introduced in class and that the mathematics questions were aligned with the NSW Maths Syllabus. Questions with low element interactivity consisted of one or two solution steps and high element interactivity solutions were comprised of three or four solution steps. It should be noted that although element interactivity may be considered subjective according to the level of expertise of participants, it had been determined that participants had limited prior knowledge of these tasks and could therefore be considered as novices. The students had been introduced to the basic concepts in the task but had not as yet developed expertise in this domain. This suggested that any difference in performance, and related cognitive load and anxiety
ratings, could be attributed to the support provided by the CLT compliant materials, compared to the CLT non-compliant materials.

As for Experiments 1 and 2, the experimental materials consisted of two parts:

Part 1 (completed during session 1) measured participants’ baseline mathematics anxiety using the Abbreviated Mathematics Anxiety Scale (AMAS). All participants completed the scale in order to determine their baseline level of mathematics anxiety. The scale consists of 9 questions answered on a likert scale ranging from 1 to 5, where a value of 1 represents low anxiety, 2 some anxiety, 3 moderate anxiety, 4 quite a bit of anxiety and 5 represents high anxiety (see Appendix R). The scores were added to provide a total anxiety score between 9 and 45 for each participant.

Part 2 included the instructional materials, as well as measures of the dependent variables: performance on algebra tasks, cognitive load, anxiety, task completion time and other participant reactions to the task, including task difficulty, importance, satisfaction and engagement. At the beginning of the booklet, participants were given written instructions and were asked to provide demographic information, which included age, gender and maths class.

Part 2 (completed during session 2) consisted of two sections: Section A and Section B. Each section had the same structure as Experiments 1 and 2 and consisted of algebra problems followed by a questionnaire for participants to complete. The only difference between the two sections was the level of complexity of the algebra problems to be solved. Section A included tasks of low element interactivity and Section B contained tasks of high element interactivity. Participants recorded their personal start and finish time for each section using their own stopwatch or the clock in classroom. As for Experiments 1 and 2, no time constraints were imposed so as not induce any potential additional anxiety. In total, participants completed 20 problems (10 each of low and high element interactivity) and 2 measures of cognitive load and anxiety (1 each following low and high element interactivity problems) during the testing phase. Part 2 provided data on performance on mathematics problems, as well as mental effort /
cognitive load (and therefore efficiency) and task anxiety from subjective responses to questions by low and high anxious learners.

Section A consisted of a set of 10 mathematics problems of low element interactivity. A maximum score of 20 was possible for a participant’s performance in each section. Two marks were allocated for a correct response, one mark was allocated for a response with either an incorrect sign or a minor arithmetical error in the final step and no marks were awarded for all other responses. Section B consisted of a set of 10 mathematics problems of high element interactivity. Again, a maximum score of 20 was possible for a participant’s performance in each section. Marking criteria was consistent with that used for Section A. Participants recorded their start and finish time for the set of ten algebra problems solved in each section.

The ten algebra questions to be solved in each section were followed by an identical short questionnaire which participants were required to complete, the same as that used in Experiment 1 and 2. The questionnaire following each set of maths questions consisted of 2 instruments:

1. Six items reporting participants’ subjective ratings of:
   - The mental effort required to complete the task;
   - The difficulty of the task;
   - The level of anxiety experienced while completing the task;
   - The level of satisfaction with performance on a task;
   - The level of importance placed on the task;
   - The level of engagement experienced while completing the task.
   Participant responses were again recorded on a 9-point likert scale ranging from 1 (extremely low) to 9 (extremely high).

2. Ten items related to different types of cognitive load (ICL, ECL and GCL) answered on a 11-point Likert Scale ranging from 0 (not at all the case) to 10 (completely the case).
In total, participants completed 20 problems (10 each of low and high element interactivity) and 2 questionnaires consisting of measures of cognitive load and anxiety (1 each following low and high element interactivity problems) during the experiment. Further details of these experimental materials can be found in Experiment 1 (refer to Section 4.2.4)

6.2.5 Procedure

The procedure for Experiment 3 varied slightly from Experiments 1 and 2 as Phase 2 and 3 were conducted over two sessions. Participants were assigned to one of two instructional conditions (CLT compliant and CLT non-compliant) using stratified random sampling following division into two categories of low anxiety and high anxiety according to their AMAS scores. Random allocation to one of two instructional conditions followed participants being divided into low and high anxiety groups, ensuring approximately even numbers of each booklet were distributed for each condition. Participants were not identified as low or high anxiety on the testing materials. The experiment was conducted during two sessions and participants in each group completed the experiment at the same time. Participants were each given one booklet in each of the two sessions. The booklet for session one included instructions, demographic information (age, gender, maths class) and AMAS questionnaire (See Appendix R). The booklet for session two included instructions and maths algebra problems to be solved and subjective measures of cognitive load and anxiety (See Appendices S and T). There were 3 phases to the experiment that are explained below. Participants were able to proceed at their own pace in Phases 2 and 3 and all finished within allocated time.

Phase 1: Introduction

All participants had previously completed some course work on the given tasks as part of the algebra component of the NSW mathematics syllabus for Stage 4. The students had some prior knowledge of the material to be used in the testing but were considered novices in the domain. As the effectiveness of the process-oriented worked examples was being tested, there was no instructional phase as part of the experiment. Students were familiar with teaching techniques that utilised worked examples.
**Phase 2: Baseline measure of anxiety and demographic questions**

Phase 2 of the experiment occurred during session one of the experiment. Participants completed the Abbreviated Mathematics Anxiety Scale (AMAS), to determine a baseline measure of anxiety (See Appendix R). Participants’ level of anxiety was used to allocate participants to test groups.

**Phase 3: Completion of Maths Tasks and Questionnaires**

Phase 3 of the experiment occurred during session two of the experiment. Instructional materials for this experiment were based on the Stage 4 outcomes of the NSW Mathematics syllabus. Participants were required to complete a worksheet (see Appendices S and T) that included a number of algebraic equations. The instructional design of the materials containing tasks to be completed by students was either CLT compliant or CLT non-compliant, with problems to be solved arranged in order of increasing complexity. Participants in the CLT compliant group received paired process-oriented worked examples for each of the mathematics problems to be completed. The worked examples had key features of each step highlighted as well as an explanation of each step. These were incorporated into the worksheet and paired with each problem to be solved. Participants in the CLT non-compliant group received no learning support materials. Participants in both conditions completed the same questionnaires after the algebra questions in each section, which provided subjective measures of cognitive load, anxiety, difficulty, importance, satisfaction and engagement experienced whilst completing the task at each level of element interactivity.

Instructions were provided for participants verbally and on the front page of the booklet, and were the same as those provided for Experiment 2. Participants were informed they were able to proceed at their own pace and were asked to record their start and finish time for each section of the maths problems using a watch or stopwatch on their phone, or the clock in the classroom. The booklets were to be completed in order and participants were asked not to go back and make any changes once each section was completed and the time was recorded. They were asked to complete all answers in the booklet provided and include all working steps in their solution for each problem. Participants were permitted to use calculators in order to minimise calculation errors.
and focus on the understanding of algebraic concepts. In addition, participants were assured that they were not being tested in any way and the worksheets completed would not form part of their assessment for their course. Once the instruction prior to the task was completed, no further verbal directions or feedback was provided to students. The researcher moved between classes continuously throughout the experiment to ensure classes progressed smoothly and consistently during the study. Teachers were provided with the following script to present to students at the completion of the testing, the same as that used at the conclusion of Experiments 1 and 2:

“Thank you for participating in this research. It is hoped the results of this research will inform future teaching practice. The paper you have just completed is not a test of your ability; do not be concerned if you found some of the questions difficult. The information gathered will allow us to compare the effectiveness of different instructional materials and the effect that the design of these materials may have on your attitudes and anxiety towards maths.”

A measure of the number of correct responses was made, and marks were allocated according to the marking scheme outlined previously (see Section 6.2.4). To ensure confidentiality, data from each booklet was recorded, identifying the student as low anxiety or high anxiety and as a participant in the CLT compliant condition or CLT non-compliant condition only.

6.3 DATA ANALYSIS

The strategy for data analysis was similar to that implemented for Experiments 1 and 2, and is explained below. Data analysis consisted of two phases. The first phase consisted of preliminary analysis of data to determine inter-rater reliability, ensuring consistency followed by identification of participants as low and high baseline maths anxiety in each Instructional Design Condition. The second phase of data analysis comprised the analysis dependent variables, and consisted of three parts. Firstly, analysis of participants’ performance and subjective measures of cognitive load across the
instructional conditions was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Element Interactivity Condition) factorial analysis. This was followed by analysis using Pearson’s Correlation coefficient to investigate the relationship between participants’ baseline maths anxiety and cognitive load regardless of instructional condition, then across conditions using a 2 (Instructional Design Condition) X 2 (Baseline Maths Anxiety) ANOVA. Part 3 considered participants’ baseline maths anxiety in the analysis of performance scores, subjective measures of cognitive load and perceived task anxiety, and additional dependent variables as necessary. This analysis was undertaken by conducting a 2 (Instructional Design Condition) x 2 (Baseline Anxiety Condition) x 2 (Element Interactivity Condition) factorial analysis. An elaboration of how these two phases of data analysis were conducted is provided below.

6.3.1 Preliminary Analysis

Inter-rater reliability
Participant booklets were marked by two independent scorers, using the marking criteria provided (refer to Section 6.2.4). On completion of marking, a comparison of marks allocated by the two independent scorers was undertaken to assess the accuracy and consistency of results between markers. Calculation of Pearson Correlation demonstrated an inter-rater reliability \( r = 1 \), indicating a perfect correlation between markers (Gao, 2012).

No Exclusion of Participants
All students who participated in session 2 had previously participated in session 1 (completion of the AMAS). Each of these participants successfully completed all parts of the experimental materials in session 2 and so data collected from all participants were included in the study.

Identifying high and low anxious participants
Each participant’s baseline level of anxiety was calculated and identified according the Abbreviated Maths Anxiety Scale (AMAS) completed during session one of the experiment. Each individual’s score was composed of the sum of their subjective
responses to 9 questions to provide a total anxiety score with a minimum of 9 and maximum of 45 possible (Hopko et al., 2003a). Additional stratified sampling techniques were applied in Experiment 3 in order to ensure homogeneous groups of participants in terms of baseline mathematics anxiety in the CLT compliant condition and the CLT non-compliant condition. A total of four groups emerge for Part 3 of the analysis of dependent variables (see Figure 6.3).

As stated in Experiment 1 (see Section 4.3.1), literature has interpreted high and low anxiety scores in a number of ways. As for Experiments 1 and 2, terciles were used to determine the low and high anxiety groups. Participants were divided into three groups and categorized as low, medium or high maths anxious based on the scores obtained on the AMAS. High maths anxious individuals were those with AMAS scores in the top third of scores in each condition and low maths anxious individuals were those with AMAS scores in the bottom third of scores for each condition. Individuals in the middle third were not included in Part 3 of the analysis for anxiety groups, although these participants did complete both session one and session two.

Table 6.1 illustrates the AMAS scores for participants in both the CLT compliant and CLT non-compliant instructional materials conditions. Scores ranged from 12 to 31 for
the CLT compliant condition and 11 to 36 for the CLT non-compliant condition. These scores were then divided into terciles. High and low anxious participants were therefore identified not solely on their AMAS score, but where that score placed them within the range of scores for individuals in the same condition. Responses determined whether participants were categorized as low or high anxiety maths anxious individuals.

Table 6.1

<table>
<thead>
<tr>
<th>Baseline AMAS Scores For Participants in Each Condition Identifying Upper And Lower Terciles</th>
<th>AMAS Score For Each Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLT compliant</td>
</tr>
<tr>
<td>Low Anxiety (LA)</td>
<td></td>
</tr>
<tr>
<td>Lower Tercile Range</td>
<td>12-20</td>
</tr>
<tr>
<td>LA n</td>
<td>19</td>
</tr>
<tr>
<td>LA Mean</td>
<td>16.55</td>
</tr>
<tr>
<td>LA SD</td>
<td>2.58</td>
</tr>
<tr>
<td>Moderate Anxiety</td>
<td></td>
</tr>
<tr>
<td>Middle Tercile Range</td>
<td>21-24</td>
</tr>
<tr>
<td>n</td>
<td>9</td>
</tr>
<tr>
<td>High Anxiety (HA)</td>
<td></td>
</tr>
<tr>
<td>Upper Tercile Range</td>
<td>25-31</td>
</tr>
<tr>
<td>HA n</td>
<td>13</td>
</tr>
<tr>
<td>HA Mean</td>
<td>27.58</td>
</tr>
<tr>
<td>HA SD</td>
<td>1.71</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Total Range</td>
<td>12-31</td>
</tr>
<tr>
<td>Total n</td>
<td>43</td>
</tr>
<tr>
<td>Total Mean</td>
<td>21.49</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.18</td>
</tr>
</tbody>
</table>

Following analysis of the data collected, highly anxious participants were identified as those in the upper tercile of anxiety scores in each condition; 29 participants from a total of 92. This translated to AMAS scores of between 25 and 31 for the CLT compliant condition.
instruction group, a total of 13 participants. Highly anxious participants had AMAS scores between 25 and 36 in the CLT non-compliant instruction group – a total of 16 participants. There were 38 participants identified as Low anxiety. Low anxious participants were identified as those in the lower tercile of anxiety scores in each condition. This translated to AMAS scores of between 12 and 20 for the CLT compliant instruction group and between 11 and 20 for the CLT non-compliant instruction group – a total of 19 participants in each group. The higher number of participants included in each tercile was the result of the addition of participants scoring the same as the cut-off point beyond the tercile limits. The upper limit of the low anxiety scores and the lower limit of the high anxiety scores were the same for each group. Scores in the middle terciles, corresponding to AMAS scores between 21 and 24 in both conditions, were not included in Part 3 of the analysis.

Due to the determination of participants’ AMAS score prior to testing, equal numbers of low and high maths anxious participants were in each condition, CLT compliant and CLT non-compliant. The upper and lower boundaries for each condition were consistent, resulting in similar baseline anxiety scores in both conditions. The use of stratified random sampling of participants to each condition after determination of baseline anxiety scores ensured similar anxiety levels of low and high anxiety participants in each condition. As a result, there was no significant difference between the anxiety scores of participants in each condition ($F(1,90) = 0.263, p = .609$). That is, the baseline measure for both low and high anxiety was consistent between groups. In addition, the difference between the anxiety scores of each experimental group was significant, ($F(3,63) = 109.684, p < .001$).

### 6.3.2 Analysis of Dependent Variables

The second phase of analysis was the analysis of dependent variables and was structured in the same way as in Experiments 1 and 2. All analyses were preceded by computation of descriptive statistics (mean, standard deviation) for all measures of performance, cognitive load and anxiety. There were three parts to the analysis undertaken, each part described in more detail in Section 4.3.2:
• Part 1: a 2 (Instructional Design) x 2 (Element Interactivity) analysis of variance (ANOVA) was conducted to compare the effectiveness of CLT compliant materials compared to CLT non-compliant material;

• Part 2: Pearson’s Correlation Co-efficient was calculated to determine the nature of the relationship between baseline maths anxiety and cognitive load, as well as a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) ANOVA to confirm findings across instructional design conditions;

• Part 3: a 2 (Instructional Design) x 2 (Baseline Anxiety) x 2 (Element Interactivity) analysis of variance (ANOVA) was calculated on participants’ performance scores, cognitive load ratings and perceived task anxiety ratings to investigate main effects of participants’ baseline maths anxiety.

As for experiments 1 and 2, any analyses that indicated significant effects were analysed further using 2 (experimental group or level of element interactivity) x 2 (dependent variable) ANOVA, t-tests (with Bonferroni corrections as required) and Cohen’s d. Results were examined for participants’ problem solving performance scores and associated completion times, cognitive load ratings and perceived task anxiety ratings. Significant interactions between element interactivity, instructional conditions and baseline maths anxiety were then analysed using T-tests and/or correlations. In addition, descriptive statistics for participants’ task completion time and for participants’ subjective ratings of task difficulty, task importance and task satisfaction were analysed. These ratings were reported in each section following completion of each set of maths questions and subjective ratings were measured using the same 9-point likert scale as the Cognitive Load Subjective Rating Scale.

In addition to the above analyses, Experiment 3 also calculated the instructional efficiency of the instructional materials in both the CLT compliant condition and CLT non-compliant condition, and for high and low anxiety participants in each condition, that is, the four experimental groups. A measure of relative efficiency of instruction was devised by Paas and van Merriënboer (1993) which used measures of performance on a relevant task and subjective ratings of cognitive load (or effort). It was proposed that combining the measures of mental effort and performance would provide “better insight” into the effectiveness and potential benefits of particular instructional designs.
and learning environments (p. 742). This allows consideration of learning outcomes for a particular instructional condition to take into account the cognitive resources required to achieve performance scores on a particular task. Although this was calculated in Experiments 1 and 2, findings were not reported in detail, as they were not significant due to the findings for performance and mental effort not being significant. Significant findings in Part 1 of results would justify calculation of instructional efficiency for Experiment 3.

In order to calculate Efficiency, mental effort \((M)\) and performance \((P)\) scores must first be converted to standardised \(z\) scores. This suggests “each unit of invested mental effort equals one unit of performance” (Paas & van Merriënboer, 1993, p. 739). The \(z\) scores are used to calculate efficiency scores for each condition according to the formula below:

\[
E = \frac{M - P}{\sqrt{2}}
\]

where \(E\) = Instructional Efficiency

\(M\) = Mental effort score

\(P\) = Performance score.

Therefore, if \(M - P < 0\), \(E\) is positive indicating efficient learning; if \(M - P > 0\), \(E\) is negative indicating inefficient learning. As the value of \(E\) increases, the efficiency associated with a particular instructional condition increases (Pollock et al., 2002). “High instructional efficiency equates to high task performance and low mental effort…and low instructional efficiency results from low task performance and high mental effort” (Sweller, Ayres & Kalyuga, 2011, p. 75).

6.4 RESULTS

The results are presented similarly to Experiments 1 and 2, that is, in three parts according to the research questions, and as discussed in Section 6.3.2. Part 3 of the results includes the additional Research Question 6 introduced in Experiment 3.
Descriptive statistics and analyses of variables beyond those addressed specifically in the research questions have been included as additional findings as appropriate, with full details of the analyses for these additional findings available in Appendix Y.

6.4.1 Part 1 – Performance and Cognitive Load across Instructional Conditions

Research Question 1 was concerned with a comparison of participants’ performance scores and ratings of cognitive load for problems of high element interactivity when using either CLT compliant instructional materials or CLT non-compliant instructional materials. This analysis was undertaken to confirm previous research findings related to the negative impact of CLT non-compliant instructional materials and tasks of high element interactivity on participants’ performance scores and subjective ratings of cognitive load. This was not confirmed in Experiments 1 and 2. Analysis did not include consideration of participants’ level of mathematics anxiety in Research Question 1.

6.4.1.1 Performance across Instructional Conditions

Performance scores were calculated for low and high element interactivity, each consisting of 10 questions and with a possible maximum score of 20, combining to give a total score out of 40. Descriptive statistics for performance scores in the CLT compliant condition and CLT non-compliant condition are shown in Table 6.2.

Table 6.2
Descriptive Statistics – Performance Scores for CLT compliant and CLT non-compliant Conditions

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CLT compliant $n = 43$</th>
<th>CLT non-compliant $n = 49$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performance Mean (SD)</td>
<td>Performance Mean (SD)</td>
</tr>
<tr>
<td>Low (/20)</td>
<td>19.09 (1.34)</td>
<td>16.35 (4.72)</td>
</tr>
<tr>
<td>High (/20)</td>
<td>13.23 (5.87)</td>
<td>7.13 (6.51)</td>
</tr>
<tr>
<td>Total (/40)</td>
<td>32.33 (6.55)</td>
<td>23.33 (9.22)</td>
</tr>
</tbody>
</table>
Overall, the total performance scores for the CLT compliant condition were higher than for the CLT non-compliant condition. This difference was significant, $F(1,90) = 28.406, p < .001$. This confirms previous research that CLT compliant instructional materials improve performance outcomes for participants.

**Performance Scores and Element Interactivity**

Participants using CLT compliant materials outperformed participants using CLT non-compliant materials when solving maths problems of low and high element interactivity. There was a significant difference in performance scores between the CLT compliant condition and the CLT non-compliant condition for tasks of low element interactivity, $F(1,90) = 13.578, p < .001$, and for tasks of high element interactivity, $F(1,89) = 21.909, p < .001$.

Table 6.2 shows for both the CLT compliant condition and the CLT non-compliant condition at higher levels of element interactivity, there was a corresponding decrease in performance scores. T-tests confirmed a significant difference between performance scores at low and high element interactivity for the CLT compliant condition, $t(84) = 6.338, p < .001$, and for the CLT non-compliant condition, $t(94) = 6.193, p < .001$. Therefore, it can be concluded maths problems to be solved were of a level of difficulty corresponding to low and high element interactivity. In addition, this supports previous research that increasing element interactivity negatively impacts performance (Sweller, 1994).

**6.4.1.2 Cognitive Load across Instructional Conditions**

Participants’ ratings of cognitive load were measured using two scales, as for Experiments 1 and 2. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992), which measures overall total cognitive load. Cognitive load was also measured using the Cognitive Load Differentiating Scale (CLDS) (Leppink et al., 2013), which differentiates between the ICL, ECL and GCL of a task. The results for both subjective cognitive load scales are presented below.
6.4.1.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992)

Mental effort ratings were recorded for tasks of low and high element interactivity using the Cognitive Load Subjective Rating Scale (CLSRS). A score between 1 and 9 was recorded on a likert scale for “Rate the mental effort required to complete the task”. Total mental effort ratings for each condition were calculated by addition of mean mental effort ratings for tasks of low and high element interactivity. Descriptive statistics for mental effort ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 6.3.

Table 6.3
Descriptive Statistics – Mental Effort Ratings (CLSRS) for CLT compliant and CLT non-compliant Conditions

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CLT compliant $n = 43$</th>
<th>CLT non-compliant $n = 49$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mental Effort Mean ($SD$)</td>
<td>Mental Effort Mean ($SD$)</td>
</tr>
<tr>
<td>Low (/9)</td>
<td>2.81 (1.30)</td>
<td>3.90 (1.82)</td>
</tr>
<tr>
<td>High (/9)</td>
<td>5.12 (1.88)</td>
<td>6.48 (1.84)</td>
</tr>
<tr>
<td>Total (/18)</td>
<td>7.93 (2.51)</td>
<td>10.24 (3.42)</td>
</tr>
</tbody>
</table>

Table 6.3 shows that the total mean mental effort rating was lower for the CLT compliant condition compared to the CLT non-compliant condition. This difference was significant, $F(1,90) = 13.372, p < .001$.

**Mental Effort Rating and Element Interactivity**

As shown in Table 6.3, participants using CLT compliant materials reported lower mental effort ratings than those participants using CLT non-compliant materials when solving maths problems of low element interactivity and high element interactivity. These differences were significant: $F(1,90) = 10.577, p = .002$; $F(1,89) = 12.158, p = .001$ respectively. This result indicates lower mental effort ratings for participants when using CLT compliant instructional materials compared to those using CLT non-compliant materials.
Table 6.3 also shows for higher levels of element interactivity, there were corresponding higher mental effort ratings for both the CLT compliant condition and the CLT non-compliant condition. T-tests confirmed a significant difference in mental effort ratings from low to high element interactivity, for both the CLT compliant condition, $t(84) = 6.613$, $p < .001$ and the CLT non-compliant condition, $t(94) = 6.711$, $p < .001$.

6.4.1.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

Ratings for each component of cognitive load were measured using the Cognitive Load Differentiating Scale (Leppink et al., 2013). Cognitive load ratings were recorded for solving maths problems of low and high element interactivity. The CLDS consists of 10 items: 3 related to ICL, 3 related to ECL and 4 related to GCL. Each item was measured using an 11-point likert scale ranging from 0 to 10. The total load for the task in each instructional condition was found by adding the cognitive load ratings for low and high element interactivity tasks, for each component of cognitive load. For the purposes of this analysis, results focused on extraneous cognitive load only.

Three items were used to measure ECL (items 4-6 on the CLDS). Possible scores range from 0 to 30, with higher scores indicating a higher load. Descriptive statistics for ECL ratings in the CLT compliant condition and CLT non-compliant condition are shown in Table 6.4.

<table>
<thead>
<tr>
<th>Table 6.4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Descriptive Statistics – Extraneous Cognitive Load for CLT compliant and CLT non-compliant Conditions</strong></td>
</tr>
<tr>
<td>Element Interactivity</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Low (/30)</td>
</tr>
<tr>
<td>High (/30)</td>
</tr>
<tr>
<td>Total (/60)</td>
</tr>
</tbody>
</table>
Table 6.4 shows participants’ total ECL ratings were higher for the CLT non-compliant condition compared to CLT compliant condition. However, this difference was not significant, $F(1,89) = 2.731, p = .102$.

**ECL Ratings and Element Interactivity**

The extraneous cognitive load refers to the load associated with the design of instructional materials. Research has shown differences in ECL to be evident when completing tasks of high element interactivity. These findings support previous research with no significant difference in ECL when using CLT compliant materials compared to CLT non-compliant materials for tasks of low element interactivity, $F(1,90) = 2.349, p = .534$. However, for tasks of high element interactivity, the ECL reported by participants using CLT non-compliant materials was higher than the ECL reported by those using CLT compliant materials. This difference was close to significant, $F(1,89) = 3.789, p = .055$.

In both the CLT compliant condition and the CLT non-compliant condition, participants’ ratings of ECL were higher at high element interactivity compared to low element interactivity. For the CLT compliant condition, an increase from low element interactivity to high element interactivity had a small effect on participants’ rating of ECL ($d = 0.36$) and this difference was not significant, $t(85) = 1.771, p = .080$. For the CLT non-compliant condition, an increase from low element interactivity to high element interactivity had a large effect on participants’ rating of ECL ($d = 0.79$) and this difference was significant, $t(93) = 3.546, p = .001$.

**6.4.1.3 Summary of Part 1 Results**

Results showed that participants achieved significantly higher performance scores when solving problems of low element interactivity compared to high element interactivity in both the CLT compliant condition and the CLT non-compliant condition. These results showed that there was a significant difference in the performance scores for participants using CLT compliant materials compared to participants using CLT non-compliant materials. Hypothesis 1, learners using CLT compliant instructional materials will outperform learners using CLT non-compliant instructional materials when solving
problems of high element interactivity, in accordance with previous CLT research, was supported. As expected, results showed that participants reported lower cognitive load when solving problems of low element interactivity compared to high element interactivity. That is, the cognitive load associated with a task corresponds with the complexity of the task. However, results from the CLDS indicate this difference was significant only when using CLT non-compliant materials. The use of CLT compliant materials meant that participants did not report significantly more extraneous load for a complex task. Results showed that there was a significant difference in the ratings of mental effort when using the CLSRS (Paas, 1992) and ECL when using the CLDS (Leppink et al., 2013), for participants using CLT compliant materials compared to participants using CLT non-compliant materials. Thus Hypothesis 2, that predicted learners using CLT compliant instructional materials would report lower cognitive load compared to learners using CLT non-compliant instructional materials when solving problems of high element interactivity, in accordance with previous CLT research, was supported.

6.4.1.4 Additional Findings for Validation of Materials

The CLDS also measured the intrinsic and germane cognitive load of a task. As in Experiment 1 and 2, analysis of these results allowed validation of our experimental materials, ICL for determining levels of element interactivity and GCL for effectiveness of CLT compliant instructional materials. Descriptive statistics for these measures can be found in Appendix Y (Table Y1 and Table Y2 respectively).

At higher levels of element interactivity, participants reported higher ICL ratings in both the CLT compliant condition and CLT non-compliant condition. Participants in both conditions reported higher ICL at high element interactivity compared to low element interactivity. Calculation of Cohen’s $d$ indicated an increase in element interactivity from low to high had a large effect size for both the CLT compliant condition, $d = 1.24$ and the CLT non-compliant condition, $d = 1.62$. This was expected as ICL is directly related to the level of element interactivity involved in a task and these results support previous findings that higher levels of element interactivity incur a higher intrinsic cognitive load. The Intrinsic Cognitive load associated with the task was significantly
greater at high element interactivity compared to low element interactivity for the CLT compliant condition, $t(84) = 5.740, p < .001$, and for the CLT non-compliant condition, $t(94) = 7.905, p < .001$ In addition, the significant difference in performance scores for Part A and Part B (refer to section 6.4.1.1) was indicative of this increased task complexity. Together, this confirms that the experimental instructional materials successfully differentiated between tasks of low and high element interactivity.

![Germane Cognitive Load](image)

*Figure 6.4.* Germane cognitive load for CLT compliant and CLT non-compliant conditions.

Consistent with findings from Experiments 1 and 2, GCL ratings were higher for the CLT compliant condition compared with the CLT non-compliant condition at high element interactivity. This indicated that CLT compliant instructional materials increased the investment of germane resources by participants for complex tasks. The difference in these ratings was very close to significant, $F(1,89) = 3.908, p = .051$. Furthermore, as shown in Figure 6.4, for participants in the CLT compliant condition, reported GCL was significantly higher for tasks of high element interactivity compared to tasks of low element interactivity, $F(1,84) = 3.954, p = .050$. This would be advantageous given the increased complexity and demands of the task. However, for participants in the CLT non-compliant condition, the reported GCL was lower for tasks of high element interactivity compared to tasks of low element interactivity, that is,
there was a decrease in germane resources invested to manage the more difficult task. However, this difference was not significant, $F(1,94) = 0.923, p = .339$.

6.4.2 Part 2 – Relationship between Cognitive Load and Baseline Mathematics Anxiety

Part 2 of the analysis of dependent variables, which focused on addressing Research Question 2, investigated the relationship between participants’ cognitive load ratings and their baseline maths anxiety, indicated by their AMAS score. This analysis was conducted to determine whether participants with high baseline mathematics anxiety reported higher cognitive load than participants with low baseline mathematics anxiety.

Descriptive Statistics and effect sizes for the mental effort and cognitive load ratings reported for low and high anxiety participants at low and high element interactivity are presented in Table 6.5.

Table 6.5
*Means, Standard Deviations, And Effect Sizes For Cognitive Load Ratings*

<table>
<thead>
<tr>
<th></th>
<th>Low Element Interactivity</th>
<th>High Element Interactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Anxiety</td>
<td>High Anxiety</td>
</tr>
<tr>
<td><strong>CLSRS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>2.95 (1.47)</td>
<td>3.93 (1.87)</td>
</tr>
<tr>
<td><strong>CLDS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICL</td>
<td>4.87 (5.99)</td>
<td>8.28 (6.29)</td>
</tr>
<tr>
<td>ECL</td>
<td>7.92 (5.09)</td>
<td>8.55 (6.05)</td>
</tr>
<tr>
<td>GCL</td>
<td>8.05 (10.59)</td>
<td>13.59 (10.30)</td>
</tr>
</tbody>
</table>

Table 6.5 shows for tasks of low element interactivity, anxiety had a medium effect on participants’ mental effort ratings, intrinsic cognitive load and germane cognitive load. For tasks of high element interactivity, anxiety had a medium effect on participants’ mental effort ratings and germane cognitive load. High baseline maths anxiety had a
small effect on participants’ ratings of ECL for tasks of both low and high element interactivity. Analysis using a one-way ANOVA revealed that participants’ baseline maths anxiety had a significant effect on participants’ ratings of mental effort for tasks of low element interactivity \((F(1,65) = 5.820, p = .019)\) and high element interactivity \((F(1,65) = 3.971, p = .049)\). As for Experiments 1 and 2, of particular interest was that participants with high baseline maths anxiety invested significantly more germane resources than participants with low baseline anxiety for both simple tasks \((F(1,65) = 4.599, p = .036)\) and complex tasks \((F(1,65) = 4.135, p = .046)\).

Pearson’s correlation coefficient was calculated between participants’ baseline maths anxiety and effort ratings from the CLSRS (Paas, 1992) and between participants’ baseline anxiety and components of cognitive load (ICL, ECL and GCL) from the CLDS (Leppink et al., 2013) for tasks of low and high element interactivity. These results are presented in Table 6.6.

Table 6.6

<table>
<thead>
<tr>
<th></th>
<th>Low Element Interactivity</th>
<th>High Element Interactivity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLSRS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effort</td>
<td>(r(92) = 0.306, p = .003)</td>
<td>(r(91) = 0.301, p = .004)</td>
</tr>
<tr>
<td><strong>CLDS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICL</td>
<td>(r(92) = 0.357, p = .001)</td>
<td>(r(91) = 0.240, p = .022)</td>
</tr>
<tr>
<td>ECL</td>
<td>(r(92) = 0.058, p = .586)</td>
<td>(r(91) = 0.096, p = .364)</td>
</tr>
<tr>
<td>GCL</td>
<td>(r(92) = 0.219, p = .036)</td>
<td>(r(91) = 0.153, p = .147)</td>
</tr>
</tbody>
</table>

Table 6.6 shows at both low and high element interactivity, a significant positive correlation was identified between participants’ AMAS score and mental effort, and between participants’ AMAS score and ICL rating. Although these correlations were not significant for participants’ ratings of ECL, as a participant’s baseline measure of maths anxiety increased, so too did their subjective measure of mental effort (CLSRS) (Paas, 1992) and their subjective measure intrinsic cognitive load (CLDS) (Leppink et al., 2013). This indicates a strong, positive correlation between AMAS scores and these two measures of cognitive load. As in experiments 1 and 2, high anxiety levels caused participants to perceive tasks to be more complex and require more mental effort. Thus,
Hypothesis 3, that predicted participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher cognitive load imposed on working memory caused by anxiety, was supported.

The impact of participants’ baseline maths anxiety on each of these measures was investigated for both the CLT compliant condition and the CLT non-compliant condition. Additional analysis was conducted using a 2 (Instructional Design Condition) x 2 (Baseline Maths Anxiety) analysis of variance (ANOVA) for participants’ perceived cognitive load measures. This allowed a comparison of cognitive load measures for participants with low baseline maths anxiety and participants with high baseline maths anxiety in both the CLT compliant condition and the CLT non-compliant condition. Participants with high baseline anxiety reported higher total mental effort ratings in both the CLT compliant condition and the CLT non-compliant condition (Refer to Table 6.5). This indicated that high anxiety had a greater impact on all measures of cognitive load in the CLT non-compliant condition, compared to the CLT compliant condition. However, at high element interactivity, there were no significant differences between the measures of cognitive load for participants with low anxiety and high anxiety on the CLT compliant condition or in the CLT non-compliant condition.

Further analysis was completed to investigate the relationship between instructional materials and participants’ baseline maths anxiety on participants’ measures of cognitive load. For tasks of high element interactivity, participants with high anxiety in the CLT compliant condition reported significantly lower mental effort ($F(1,27) = 9.42$, $p = .005$), significantly lower ICL ($F(1,27) = 6.35$, $p = .018$), significantly lower ECL ($F(1,27) = 4.58$, $p = .042$), significantly higher GCL ($F(1,27) = 10.60$, $p = .003$), compared to participants with high anxiety in the CLT non-compliant condition. The additional cognitive load experienced by high maths anxiety was increased further when using CLT non-compliant materials when solving problems of high element interactivity.
Part 3 of the results addressed Research Questions 3, 4 and 5, as well as the Exploratory Questions 1 and 2, and was based on participants’ baseline maths anxiety groupings within each condition. This allowed the investigation of how instructional materials designed according to CLT principles may provide support to learners with high maths anxiety. As previously stated, this included an additional research question (Research Question 5) to investigate how instructional materials designed according to CLT principles may additionally provide support to learners with high maths anxiety when solving algebra problems of low element interactivity.

The analysis undertaken reports findings for participants’ total scores and subjective ratings of cognitive load. Analysis considered the level of element interactivity and participants’ baseline maths anxiety. Analyses of variables beyond those addressed specifically in the research questions, such as task completion time, task difficulty, task satisfaction and task importance (see Section 6.3.2) are included as additional findings as appropriate with full details of these descriptive statistics and analyses available in Appendix Y (Table Y3).

6.4.3.1 Performance

For Research Question 3, data for participants’ performance scores were analysed based on baseline mathematics anxiety levels, that is, low and high mathematics anxiety categories in each condition. Descriptive results for these four groups are presented in Table 6.7.
Table 6.7

Descriptive Statistics – Performance with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA ( n = 19 )</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low /20</td>
<td>18.68 (1.60)</td>
</tr>
<tr>
<td>High /20</td>
<td>12.00 (6.87)</td>
</tr>
<tr>
<td>Total /40</td>
<td>30.68 (7.41)</td>
</tr>
</tbody>
</table>

Table 6.7 shows at higher levels of element interactivity, mean performance scores were lower across all groups. A one-way ANOVA for performance scores confirmed a significant effect between the four groups at low element interactivity, \( F(3,63) = 8.512, p < .001 \), at high element interactivity, \( F(3,63) = 6.258, p = .001 \) and overall, \( F(3,63) = 8.743, p < .001 \). Participants with both low and high anxiety higher performance scores when using CLT compliant materials compared to CLT non-compliant materials. The highest performance score overall was for participants with high baseline anxiety levels using CLT compliant instructional materials. At high element interactivity, the CLT compliant high anxiety group (CCHA) attained higher performance scores than all other groups. Results of the one-way ANOVA showed significantly higher performance scores for the CLT compliant high anxiety group (CCHA) compared to the CLT non-compliant high anxiety group (CNHA) at low element interactivity, \( F(1,27) = 9.267, p = .005 \) and at high element interactivity, \( F(1,27) = 20.033, p < .001 \). Thus, Hypothesis 4, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity, was supported.

### 6.4.3.2 Extraneous Cognitive Load

Research Question 4 investigated whether participants with high baseline mathematics anxiety presented with CLT compliant materials experienced lower extraneous cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant materials when solving problems of high element interactivity.
Participants’ ratings of cognitive load were measured using two scales. Self reported mental effort ratings were established using the Cognitive Load Subjective Rating Scale (CLSRS) (Paas, 1992). Participants’ subjective rating of extraneous cognitive load was measured using items 4-6 from the Cognitive Load Differentiating Scale (CLDS) (Leppink et al., 2013). The results for both subjective cognitive load scales are presented below.

6.4.3.2.1 Subjective Mental Effort Rating using the CLSRS (Paas, 1992).

For Research Question 4, data related to participants’ mental effort ratings were analysed based on participants’ baseline mathematics anxiety. Descriptive results for the four experimental groups are presented in Table 6.8.

Table 6.8

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 19</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.63 (1.34)</td>
</tr>
<tr>
<td>High</td>
<td>4.95 (2.17)</td>
</tr>
<tr>
<td>Total</td>
<td>7.58 (3.13)</td>
</tr>
</tbody>
</table>

Analysis using a one-way ANOVA revealed that the experimental group, incorporating the instructional condition and participants’ baseline maths anxiety, had a significant effect on participants’ mental effort ratings, when solving maths problems of low element interactivity, $F(3,63) = 6.346, p = .001$, when solving maths problems of high element interactivity, $F(3,63) = 5.785, p = .001$, and overall, $F(3,63) = 8.994, p < .001$. These results show that the CLT non-compliant high anxiety group (CNHA) reported the highest mental effort rating compared to all other groups. The mental effort rating for the CLT non-compliant high anxiety group (CNHA group) was significantly higher than the CLT compliant high anxiety group (CCHA group) when solving problems of low element interactivity, $F(1,27) = 15.820, p < .001$ and when solving maths problems of high element interactivity, $F(1,27) = 9.425, p = .005$. 
As shown in Figure 6.5, solving maths problems of high element interactivity required greater mental effort than solving maths problems of low element interactivity when using both CLT compliant and CLT non-compliant instructional materials. Participants with high baseline anxiety reported higher mental effort ratings in both conditions. At high element interactivity, there was no significant difference in mental effort ratings for low anxiety participants and high anxiety participants when using CLT compliant materials \((F(1,30) = 0.808, p = .376)\) or when using CLT non-compliant materials, \((F(1,33) = 3.464, p = .072)\). Both low and high anxiety participants reported higher mental effort ratings when using CLT non-compliant instructional materials compared to those using CLT compliant materials.

### 6.4.3.2.2 Subjective ECL Rating using the CLDS (Leppink et al., 2013)

For Research Question 4, data related to participants’ extraneous cognitive load ratings were analysed further based on participants’ baseline mathematics anxiety. Descriptive statistics for the four experimental groups are presented in Table 6.9.

![Cognitive Load (CLSRS)](image_url)
Table 6.9

Descriptive Statistics – Extraneous Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA ( n = 19 )</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>7.74 (4.98)</td>
</tr>
<tr>
<td>High</td>
<td>10.74 (8.50)</td>
</tr>
<tr>
<td>Total</td>
<td>18.47 (11.30)</td>
</tr>
</tbody>
</table>

Table 6.9 shows mean ECL ratings for groups incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions for tasks of low and high element interactivity. Results of the one-way ANOVA showed the experimental group had a significant effect on ECL ratings when completing problems of high element interactivity, \( F(3,63) = 5.127, p = .003 \).

Figure 6.6. Graph of extraneous cognitive load for experimental groups.

Figure 6.6 shows in the CLT non-compliant condition, highly anxious participants (CNHA) reported higher ECL ratings compared to low anxious participants (CNLA). This difference was not significant, \( t(33) = 1.056, p = .298 \). In the CLT compliant condition, highly anxious participants (CCHA) reported lower extraneous cognitive load compared to low anxious participants (CCLA). This difference was not significant, \( t(30) = 0.627, p = .535 \). Furthermore, the lowest ECL ratings at both low and high element interactivity were for participants in the CCHA group. This suggests the
importance and effectiveness of CLT compliant materials for high maths anxious learners. Results of one-way ANOVA indicate the mean ECL rating for the CCHA group was significantly lower than the mean ECL rating for the CNHA group when solving maths problems of high element interactivity, $F(1,27) = 4.581, p = .042$.

As discussed above, the combination of high anxiety and CLT non-compliant instructions significantly increased participants’ reported extraneous cognitive load when compared to other groups. At high element interactivity, participants with high baseline anxiety using CLT non-compliant materials (CNHA) reported significantly higher mental effort (using the CLSRS) and significantly higher extraneous cognitive load (using the CLDS) than participants with high baseline anxiety using CLT compliant materials (CCHA). Thus, Hypothesis 5: participants with high baseline maths anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant instructional materials when solving mathematics problems of high element interactivity, was supported.

6.4.3.2.3 Additional Findings for Mental Effort

Additional findings related to analysis of the relationship between mental effort and participants’ task completion time, reported task difficulty and, given significant results for performance and mental effort in this experiment, instructional efficiency. Additional analysis related to cognitive load and expertise was not conducted in Experiment 3 as participants were all considered to be novices in relation to the content presented. Analysis of task completion time showed a significant relationship with participants’ reported mental effort and higher levels of element interactivity incurred corresponding higher task completion times. This may suggest greater investment of germane resources for complex tasks, when using CLT compliant materials. Analysis of task difficulty ratings showed significant advantages for participants with high maths anxiety using CLT compliant materials. Efficiency scores indicated significant instructional advantage for highly anxious participants using CLT compliant materials for tasks of both low and high element interactivity.
Of particular interest were findings related to participants’ ratings of task difficulty. Descriptive Statistics for Task Difficulty can be found in Appendix Y (Table Y3). The CNHA group reported the highest ratings of task difficulty compared to all other groups. Analysis of perceived task difficulty using t-tests showed the CNHA group reported significantly higher task difficulty compared to the CCHA at low element interactivity ($t(27) = 3.069, p = .005$), at high element interactivity ($t(27) = 3.320, p = .003$) as well as for total task difficulty ratings ($t(27) = 3.704, p = .001$). Importantly, the use of CLT compliant materials resulted in participants with high anxiety to report similar ratings of task difficulty to participants with low baseline anxiety. There was no significant difference in the ratings of task difficulty between the CCLA and CCHA groups, $t(30) = 0.152, p = .880$. This would suggest the use of CLT compliant materials successfully negated the impact of high anxiety, in terms of task difficulty, for these participants.

Analysis of calculated instructional efficiency using one-way analysis of variance indicated superior instructional efficiency when using CLT compliant materials compared to CLT non-compliant materials at low element interactivity $F(1,89) = 22.555, p < .001$ and high element interactivity $F(1,89) = 23.578, p < .001$. T-tests reveal the mean instructional efficiency score was significantly higher for the CCHA group compared to the CNHA when solving problems of low element interactivity $t(27) = 5.018, p < .001$ and high element interactivity $t(27) = 5.007, p < .001$. The significantly higher instructional efficiency indicates higher performance scores in conjunction with lower mental effort ratings when using CLT compliant materials compared to CLT non-compliant materials. This suggests the importance of CLT compliant materials for instructional efficiency for highly anxious learners when solving problems of low and high element interactivity. Descriptive statistics for instructional efficiency can be found in Appendix Y (Table Y4).

**6.4.3.3 Intrinsic and Germane Cognitive Load**

For Exploratory Question 1, data for participants’ subjective ratings of intrinsic cognitive load and germane cognitive load were analysed according to participants’ baseline mathematics anxiety and participants’ instructional condition. This was done in
order to investigate the impact of high baseline mathematics anxiety on ICL and GCL when presented with CLT compliant instructional materials compared to CLT non-compliant instructional materials when solving maths problems of high element interactivity. These ratings were measured using the CLDS.

6.4.3.3.1 Intrinsic Cognitive Load

Descriptive statistics for the subjective ratings of ICL for the four experimental groups are presented in Table 6.10.

Table 6.10
Descriptive Statistics – Intrinsic Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA n = 19</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>5.05 (6.14)</td>
</tr>
<tr>
<td>High</td>
<td>12.11 (8.35)</td>
</tr>
<tr>
<td>Total</td>
<td>17.16 (11.20)</td>
</tr>
</tbody>
</table>

Table 6.10 shows data for ICL incorporating anxiety conditions for CLT compliant and CLT non-compliant conditions at low and high element interactivity. Results of the one-way ANOVA for ICL ratings showed a significant effect between the four groups at low element interactivity, $F(3,63) = 3.226, p = .028$, high element interactivity, $F(3,63) = 6.546, p = .019$ and overall, $F(3,63) = 5.543, p = .006$. The CLT non-compliant high anxiety group (CNHA) reported higher ICL ratings at low and high element interactivity compared to the CLT compliant high anxiety group (CCHA). This difference was significant at low element interactivity, $F(1,27) = 4.467, p = .044$, and at high element interactivity, $F(1,27) = 6.348, p = .018$. These results confirmed that a combination of CLT non-compliant materials and high maths anxiety contribute to higher ICL ratings.
Figure 6.7 shows higher levels of element interactivity resulted in higher ratings of ICL for each group. In both CLT compliant and CLT non-compliant conditions, highly anxious participants reported higher ICL ratings than low anxious participants. This difference was not significant in the CLT compliant condition ($t(30) = 0.451, p = .655$) but was significant for the CLT non-compliant condition ($t(33) = 2.537, p = .016$).

Overall, high anxiety resulted in a higher reported ICL rating. Reported ICL ratings were higher still with use of CLT non-compliant instructional materials, with the CNHA group reporting the highest ICL at low and high element interactivity. This supports the findings from Experiments 1 and 2 that high anxiety increased participants’ perceived ICL. CLT non-compliant instructional materials increased the ICL of a complex task for highly anxious participants. In addition, findings from this experiment indicated highly anxious participants reported significantly lower intrinsic cognitive load (ICL ratings) when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials (CCHA) compared to highly anxious participants using CLT non-compliant instructional materials (CNHA).

### 6.4.3.3.2 Germane Cognitive Load

Descriptive statistics for the subjective ratings of GCL for the four experimental groups are presented in Table 6.11.
Table 6.11

Descriptive Statistics – Germene Cognitive Load with Anxiety Groupings

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA (n = 19)</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>6 (9.20)</td>
</tr>
<tr>
<td>High</td>
<td>9.21 (9.03)</td>
</tr>
<tr>
<td>Total</td>
<td>15.21 (14.63)</td>
</tr>
</tbody>
</table>

Table 6.11 shows that for both low and high anxiety participants, an increase in element interactivity resulted in a concomitant increase in reported GCL when using CLT compliant instructional materials. Results from the one-way ANOVA for GCL ratings indicated a significant main effect for GCL between the four groups, \(F(63,3) = 4.473, p = .007\). As in Experiment 1, the trend for participants using CLT non-compliant materials to invest less germane resources at high element interactivity was again evident. In addition, in the CLT non-compliant condition, there was no significant difference in GCL ratings between low anxiety participants (CNLA) and high anxiety participants (CNHA), \(t(33) = 0.100, p = .921\).

![Figure 6.8. Graph of germane cognitive load for experimental groups.](image)
Figure 6.8 shows that participants using CLT compliant materials to reported higher GCL for tasks of high element interactivity compared to tasks of low element interactivity. The CCHA group reported significantly higher GCL compared to all other groups at both low and high element interactivity. Consequently, results for GCL ratings of high anxiety participants are particularly interesting. Participants using CLT compliant materials reported higher GCL ratings at high element interactivity compared to low element interactivity, in order to support learning and enhance performance on complex tasks. T-tests indicated the GCL reported by the CCHA group was significantly greater than the CNHA group when solving complex maths problems, $t(27) = 3.255, p = .003$, and overall, $t(27) = 2.547, p = .017$. The use of CLT compliant materials for highly anxious participants was particularly beneficial, with t-tests revealing significantly greater GCL ratings for the CCHA group compared to the CCLA group when solving problems of low element interactivity, $t(30) = 2.949, p = .006$, high element interactivity, $t(30) = 3.604, p = .001$, and overall, $t(30) = 3.812, p = .001$. As in previous experiments, at high element interactivity, the reported GCL ratings were lower for highly anxious participants using CLT non-compliant materials compared to CLT compliant materials. For the CNHA group, there was no significant increase in reported GCL for tasks of high element interactivity compared to tasks of low element interactivity, $t(30) = 0.524, p = .604$, with mean GCL ratings lower at high element interactivity compared to low element activity.

CLT compliant materials appeared to be of particular benefit to high anxiety participants due to the significantly increased investment of germane resources for complex tasks. Highly anxious participants reported higher germane cognitive load (GCL ratings), indicating greater investment of germane resources, when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials compared to highly anxious participants using CLT non-compliant instructional materials. This would be due to additional working memory resources being available as a result of superior instructional design.
6.4.3.3.3 Additional Findings for Germane Cognitive Load

Additional analysis of the relationship between germane cognitive load and participants’ subjective ratings of task importance and task satisfaction was conducted. As indicated by findings in Experiments 1 and 2, analysis of these measures may provide insight into the results for participants’ reported GCL. The investment of germane resources in a task by a learner may be influenced by how important a task is considered. In addition, as a result of investing germane resources into a task, learners may then experience greater satisfaction regarding their performance on completion of the task. Further details related to these materials can be found in Section 4.2.4 and descriptive statistics relevant to these additional findings related to task importance and task satisfaction can be found in Appendix Y.

For tasks of high element interactivity, the subjective rating of task importance was higher for participants using CLT compliant materials compared to participants using CLT non-compliant materials. For participants using CLT non-compliant materials, the task importance ratings were lower for tasks of high element interactivity compared to tasks of low element interactivity. Furthermore, at high element interactivity, the subjective ratings of task importance for high anxiety participants using CLT compliant materials (CCHA) were significantly higher than those using CLT non-compliant materials (CNHA), $t(33) = 2.203, p = .035$. Calculation of Pearson’s Correlation Coefficient showed a significant, positive correlation between GCL ratings and task importance, $r = .555, n = 91, p < .001$. Therefore, as in Experiments 1 and 2, this confirmed the significantly greater investment of germane resources by participants who placed significantly greater importance on the task.

Participants with high baseline maths anxiety reported greater task satisfaction when using CLT compliant materials compared to those using CLT non-compliant materials. Analysis using t-tests was performed and showed a significant difference in the level of task satisfaction for high anxiety participants using CLT compliant materials and CLT non-compliant materials. This difference was significant at low element interactivity, $t(27) = 2.836, p = .009$, and high element interactivity, $t(27) = 2.459, p = .021$ and for total task satisfaction ratings, $t(27) = 3.123, p = .004$. Calculation of Pearson’s
Correlation Coefficient showed a significant, positive correlation between GCL ratings and task satisfaction, $r = .384$, $n = 91$, $p < .001$. This suggests that the use of CLT compliant materials, perhaps as a consequence of having increased the investment of germane resources in a complex task, participants report higher ratings of task satisfaction.

### 6.4.3.4 Perceived Task Anxiety Ratings

For Exploratory Question 2, data for participants’ perceived task anxiety were analysed according to participants’ baseline mathematics anxiety and participants’ instructional condition. This was done in order to investigate whether learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials when solving maths problems of high element interactivity. Descriptive statistics for the perceived task anxiety ratings of the four groups are presented in Table 6.12.

#### Table 6.12

*Descriptive Statistics – Perceived task Anxiety Ratings with Anxiety Groupings*

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA $n = 19$</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.37 (1.83)</td>
</tr>
<tr>
<td>High</td>
<td>3.32 (2.31)</td>
</tr>
<tr>
<td>Total</td>
<td>5.68 (3.92)</td>
</tr>
</tbody>
</table>

Table 6.12 shows perceived task anxiety was higher at high element interactivity compared to low element interactivity for all groups. This result confirmed that greater task complexity (higher element interactivity) increased the level of perceived task anxiety experienced. As shown in Table 6.12, perceived task anxiety was higher for participants with higher levels of baseline maths anxiety compared to those with low baseline maths anxiety at all levels of element interactivity, for both the CLT compliant condition and the CLT non-compliant condition. At high element interactivity, this
difference was not significant for the CLT compliant condition, \( F(1,28) = 1.182, \ p = .286 \), but was significant for the CLT non-compliant condition, \( F(1,31) = 10.512, \ p = .003 \). The experimental group had a significant effect on the overall perceived task anxiety rating, \( F(3,63) = 5.540, \ p = .002 \), confirming a relationship between element interactivity, CLT compliant instructional materials and anxiety. The CLT compliant low anxiety group (CCLA) had the lowest perceived task anxiety at all levels of element interactivity, compared to all other groups.

![Graph of perceived task anxiety for each experimental group.](image)

Figure 6.9. Graph of perceived task anxiety for each experimental group.

These findings were analysed further using t-tests. These results indicated the mean perceived task anxiety rating for the CNHA group was significantly higher than the CNLA group when solving problems of low element interactivity, \( t(33) = 2.365, \ p = .024 \); when solving problems of high element interactivity, \( t(33) = 3.575, \ p = .001 \); and overall, \( t(33) = 3.662, \ p = .001 \). Figure 6.9 shows the increase in perceived task anxiety for highly anxious participants compared to low anxious participants was greater when using CLT non-compliant materials compared to when using CLT compliant materials. This may be due to a higher baseline maths anxiety level, but not completely, as similar significant differences were not found when comparing the CCLA and CCHA groups. In addition, when solving maths problems of high element interactivity, the CNHA group had significantly higher perceived task anxiety ratings than the CCHA group, \( t(27) = 2.406, \ p = .023 \). Of importance is that there was no significant difference in the baseline maths anxiety of the CCHA and CNHA groups.
Overall, high anxiety participants in the CLT compliant materials condition reported lower levels of perceived task anxiety ratings compared to participants in the CLT non-compliant condition when completing tasks of low and high element interactivity. These results confirmed an increase in task complexity (element interactivity) led to higher ratings of perceived task anxiety when using CLT non-compliant materials. The CLT non-compliant high anxiety group (CNHA group) experienced significantly higher perceived task anxiety levels than the CLT compliant high anxiety group (CCHA) when solving problems of high element interactivity. When completing tasks of high element interactivity, perceived task anxiety was alleviated by the learning support associated with the use of CLT compliant instructional materials.

### 6.4.3.5 High Anxiety and Cognitive Load of Tasks with Low Element Interactivity

Research Question 5 investigated whether participants with high baseline maths anxiety presented with CLT compliant materials achieved higher performance scores and reported lower cognitive load than participants with high baseline maths anxiety presented with CLT non-compliant materials when solving problems of low element interactivity. Participants’ performance scores and ratings of cognitive load was reported at both low and high element interactivity. The results for Experiment 3 so far have confirmed the benefit of CLT compliant materials for high anxiety participants when completing tasks of high element interactivity. Instructional conditions have previously been found to not affect performance and cognitive load for tasks of low element interactivity. This was due to the load associated with simple tasks considered insufficient to necessitate consideration of the instructional design. However, because anxiety places an additional burden on working memory, worked examples may also be useful for highly anxious learners when solving problems of low element interactivity. Analysis of data was conducted to compare performance scores and mental effort ratings of highly anxious participants for maths tasks of low element interactivity. The mean performance score of the CCHA group (Mean = 19.38, SD = 1.26) was significantly higher than the CNHA group (Mean = 14.25, SD = 6.49), $F(1,27) = 9.267$, $p = .005$ for tasks of low element interactivity. There was also a significant difference in the reported mental effort of tasks of low element interactivity, the mean rating for
the CCHA group (Mean = 2.69, SD = 0.95) being significantly lower than the CNHA group (Mean = 4.94, SD = 1.84), $F(1,27) = 15.820, p < .001$. Consequently, significant results for both performance and mental effort also generate significantly higher instructional efficiency scores for CCHA group compared to CNHA group, $F(1,27) = 25.180, p < .001$.

The CLDS was used to measure individual components of cognitive load, which allowed analysis of cognitive load in terms of ICL, ECL and GCL. Analyses of the components of cognitive load also revealed CLT compliant materials reduced ICL and ECL for high anxiety participants when solving problems of low element interactivity. ICL ratings were significantly lower for the CCHA group (Mean = 5.69, SD = 6.79) compared to the CNHA group (Mean = 10.38, SD = 5.15), $F(1,27) = 4.467, p = .044$ and the effect size was large, $d = 0.78$. The ECL ratings were lower for the CCHA group (Mean = 7.23, SD = 7.63) compared to the CNHA group (Mean = 9.63, SD = 4.36). However, this difference was not significant, $F(1,27) = 1.128, p = .298$ and the effect size was small, $d = 0.39$. Finally, when solving maths problems of low element interactivity, highly anxious students also invested more germane resources to the task when using CLT compliant materials (Mean = 16.77, SD = 11.42) compared to CLT non-compliant materials (Mean = 11, SD = 8.82). This difference was not significant, $F(1,27) = 2.359, p = .136 (d = 0.57)$. However, as these were simple tasks, additional germane resources were probably not required to successfully complete the task.

These results support Hypothesis 6: when solving mathematics problems low in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) will achieve higher performance scores and report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group). This was due to CLT compliant instructional materials providing learning support when WM resources are consumed by anxiety. The CLT compliant high anxiety group (CCHA group) experienced significantly lower intrinsic cognitive load and mental effort compared to the CLT non-compliant high anxiety group (CNHA group) on mathematics tasks of low element interactivity. Anxiety uses working memory resources when
solving maths problems of low element interactivity and the load associated with this was significantly alleviated by the use of CLT compliant instructional materials.

6.5 DISCUSSION

The overall purpose of this experiment, as for Experiments 1 and 2, was to investigate whether CLT compliant instructional materials, that is, worked examples, could support learners with high mathematics anxiety to solve complex algebra problems. Experiment 3 was conducted in a secondary school setting and involved participants with low or high baseline maths anxiety solving maths tasks of low and high element interactivity using either CLT compliant materials or CLT non-compliant materials. This experiment also attempted to address limitations identified in Experiments 1 and 2, by using stratified distribution of participants between conditions in order to ensure homogeneous grouping of participants in terms of baseline maths anxiety. Furthermore, adjustments were made to the instructional materials in order to create more polarising instructional conditions. Adjustments were made in terms of the design of instructional materials: two conditions were more distinctly CLT compliant or CLT non-compliant, and in terms of the content of instructional materials: tasks to be completed were 10 problems of low element interactivity and 10 problems of high element interactivity only. Furthermore, participants in this experiment had similar levels of expertise regarding the algebra content used. All participants were considered novices in order to minimize any influence expertise may have on participant responses and the level of element interactivity associated with a task.

There were five main aims for this experiment. Firstly, as for Experiments 1 and 2, it was necessary to confirm previous research that has shown that learners perform better and report lower cognitive load for tasks of high element interactivity when presented with instructional materials designed in accordance with the principles of cognitive load theory than when presented with instructional materials not designed in accordance with CLT principles. Secondly, learner anxiety and cognitive load were investigated to confirm the relationship between these two measures established in Experiments 1 and 2. Thirdly, this experiment examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element
interactivity by improving performance scores and reducing cognitive load. Fourthly, Experiment 2 examined whether worked examples could assist learners with high mathematics anxiety when solving maths problems of high element interactivity by reducing perceived task anxiety. Finally, it was considered whether CLT effects, previously relevant for tasks of high element interactivity only, were significant for highly anxious students when solving problems of low element interactivity as well. Anxiety adds working memory load to a learning task. As a result, cognitive load effects may be evident for highly anxious learners for less complex tasks. CLT compliant materials may therefore provide learning support for highly anxious learners for tasks of low element interactivity, as well as for tasks of high element interactivity.

Five research questions and 2 exploratory questions guided this investigation. This included an additional research question, not considered in Experiments 1 and 2, which investigated learning support for highly anxious learners when solving problems of low levels of element interactivity. This section will address each research question and the main findings will be discussed in the context of other research.

### 6.5.1 Performance and Cognitive Load across Instructional Conditions

The first research question was: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

Firstly, it was expected that when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would outperform participants presented with CLT non-compliant instructional materials on performance scores, due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 1). Performance scores were significantly lower for tasks of high element interactivity compared to tasks of low element interactivity, in both the CLT compliant condition and the CLT non-compliant condition. This was consistent with previous research findings (Sweller, 1994). Findings showed for tasks of high element interactivity, the performance scores of participants
provided with CLT compliant instructional materials were significantly higher than performance scores of participants provided with CLT non-compliant materials (refer to section 5.4.1.1). Thus, hypothesis 1 was supported.

Secondly, it was expected when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials would report lower cognitive load than participants presented with CLT non-compliant instructional materials due to the reduction of extraneous cognitive load imposed by CLT compliant instructional materials (Hypothesis 2). Participants reported significantly higher mental effort ratings for tasks of high element interactivity compared to tasks of low element interactivity in both the CLT compliant condition and the CLT non-compliant condition. Furthermore, using the CLDS (Leppink et al., 2013), an increase from low element interactivity to high element interactivity resulted in a concomitant increase in ECL ratings when using both CLT compliant materials and CLT non-compliant materials. However, this difference was significant only when using CLT non-compliant materials. The findings showed that the cognitive load ratings of participants provided with CLT compliant materials were lower than cognitive load ratings of participants provided with CLT non-compliant materials (refer to section 6.4.1.2). These findings were significant for ratings of mental effort (Paas, 1992) which is composed in part of ECL, but not significant for extraneous cognitive load ratings (Leppink et al., 2013). Thus, hypothesis 2 was partially supported.

6.5.2 Cognitive Load and Baseline Mathematics Anxiety

Research Question 2 was: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low and high element interactivity?

It was predicted that participants with high baseline mathematics anxiety would report higher cognitive load than participants with low baseline mathematics anxiety due to a higher load imposed on working memory caused by anxiety (Hypothesis 3). At both low and high element interactivity, there was a significant positive correlation between participants’ baseline maths anxiety and subjective ratings of mental effort using the
CLSRS (Paas, 1992), and ICL using the CLDS (Leppink et al., 2013) (refer to Table 6.6). These results confirmed Hypothesis 3 and thus corroborated the relationship between anxiety and cognitive load established in Experiments 1 and 2.

This again showed that anxiety places a burden on working memory and is therefore an important factor in CLT research. There was an additional load placed on working memory as a result of anxious thoughts during the learning task. This load was exacerbated by the use of CLT non-compliant instructional materials. Importantly, this load was alleviated with the use of CLT compliant instructional materials. Participants with high baseline maths anxiety reported significantly lower mental effort, ICL and ECL, and significantly higher GCL, when using CLT compliant materials compared to those using CLT non-compliant materials.

6.5.3 Problem solving Performance

The third research question was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems of high element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials (CCHA group) would outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials (CNHA group) on performance scores, due to the reduction of extraneous cognitive load and increase in germane cognitive load afforded by CLT compliant instructional materials (Hypothesis 4). These findings showed that highly anxious participants achieved significantly higher performance scores when solving complex (high element interactivity) mathematics problems while using CLT compliant instructional materials (CCHA) compared to highly anxious participants using CLT non-compliant instructional materials (CNHA) (refer to Table 6.7). Thus Hypothesis 4 was supported. High anxiety had a negative effect on the performance scores of participants using both
CLT compliant and CLT non-compliant materials. However, for highly anxious participants, CLT compliant instructions resulted in significantly higher performance scores compared to CLT non-compliant materials when solving complex problems. These results showed that although performance was negatively impacted by both high maths anxiety and high element interactivity, the use of CLT compliant materials provided support for highly anxious participants. The use of CLT non-compliant materials was detrimental to performance, especially for participants with high maths anxiety.

6.5.4 Extraneous Cognitive Load

Cognitive load was measured using scales based on the Cognitive Load Subjective Rating Scale (Paas, 1992) for mental effort ratings, and the recently developed instrument for measuring different types of cognitive load (Leppink et al., 2013) for ratings of extraneous cognitive load. Similar to Experiments 1 and 2, results for cognitive load ratings have been presented and explained based on both of these scales. Research question 4 was: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was expected that when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials would report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials, due to the reduction of extraneous cognitive load afforded by CLT compliant instructional materials (Hypothesis 5).

Overall, an increase in element interactivity generated a corresponding increase in mental effort ratings for all groups (refer to Table 6.8), which was expected given the increased complexity of the task. Participants with high maths anxiety using CLT non-compliant materials (CNHA group) reported the highest mental effort when solving
maths problems of both low and high element interactivity. The mental effort rating for the CLT non-compliant high anxiety group (CNHA group) was significantly higher than the CLT compliant high anxiety group (CCHA group) when solving maths problems of high element interactivity. This suggests that CLT compliant materials supported highly anxious learners when solving tasks of high levels of element interactivity (refer to Figure 6.4).

The ECL associated with a task was higher at higher levels of element interactivity (refer to Table 6.9). This load was lower with the use of CLT compliant instructional materials, with ECL ratings of the CCHA group being significantly lower than the ECL ratings of the CNHA group at high element interactivity (refer to Section 6.4.3.2.2). CLT compliant materials therefore reduced the perceived ECL of a task of high element interactivity for highly anxious participants. The combination of high anxiety and CLT non-compliant instructions significantly increased participants’ reported extraneous cognitive load when compared to all other groups. Interestingly, the CCHA group reported the lowest ECL ratings compared to all other groups. Participants in this experiment were familiar with the use of worked examples in maths instruction and their provision effectively supported learning for high anxiety participants, particularly when solving complex tasks.

These findings indicated that for highly anxious learners, subjective mental effort ratings and subjective ratings of ECL were significantly lower when using CLT compliant materials compared to when using CLT non-compliant materials. Thus, Hypothesis 5 was supported. This supports previous research that suggests the use of worked examples reduces the ECL of a task (Paas et al., 2003b).

In addition to Hypothesis 5 being confirmed, the following interesting results emerged regarding task completion time, instructional efficiency and task difficulty (refer to Section 6.4.3.2.3).

Firstly, the time taken to complete a task was greater for all groups for tasks of higher element interactivity. The use of CLT compliant materials and high baseline anxiety significantly increased the time taken to complete problems at low levels of element
interactivity. This suggests the CCHA group made use of worked examples while solving problems of low element interactivity. There was no significant difference in completion times at high element interactivity. However, the increased effort and time associated with tasks of high element interactivity for highly anxious students translated into significantly greater performance scores for the maths tasks completed when using CLT compliant materials only (refer to Table 6.7).

The instructional efficiency associated with the use of CLT compliant instructional materials was confirmed. Participants using CLT compliant materials had significantly higher efficiency scores and for participants with high anxiety, the instructional efficiency scores were significantly higher at both low and high element interactivity (refer to Section 6.4.3.2.3).

Finally, participants’ ratings of task difficulty followed the same pattern as mental effort. This finding supports research that has used measures of task difficulty in place of mental effort (Marcus et al., 1996). An increase in element interactivity resulted in a concomitant increase in the perceived difficulty of a task when using both CLT compliant materials and CLT non-compliant materials. High anxiety increased the perceived difficulty of a task when using CLT non-compliant materials only. The use of CLT compliant materials reduced task difficulty compared to CLT non-compliant materials for highly anxious participants. This difference was significant at low and high element interactivity. At high element interactivity, there was no significant difference in the reported task difficulty between low and high anxiety participants.

6.5.5 Intrinsic and Germane Cognitive Load

Exploratory question 1 was: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials? Measurement of the individual components of cognitive load using the CLDS (Leppink et al., 2013) allowed an investigation into any effects anxiety may have on ICL and GCL when solving complex tasks.
**Intrinsic Cognitive Load**

This research investigated whether high anxiety impacted participants’ subjective rating of ICL, and also whether this differed with the use of CLT compliant materials compared to CLT non-compliant materials. These findings suggest high anxiety impacted the intrinsic cognitive load of tasks of low and high element interactivity, and ICL ratings were significantly higher when using CLT non-compliant materials compared to CLT compliant materials. ICL ratings were higher at higher levels of element interactivity for all groups. This indicated the tasks were appropriately categorized as low and high element interactivity. As in Experiments 1 and 2, high baseline maths anxiety resulted in higher ICL ratings for participants in both instructional conditions. However, this increase was significant in the CLT non-compliant condition only. The ICL ratings of participants using CLT compliant materials were significantly less than the ICL ratings of participants using CLT non-compliant materials. The highest ICL ratings at both levels of element interactivity and overall was for the CNHA group. The difference in ICL ratings between the CCHA group and CNHA group was significant (refer to Section 6.4.3.1). Participants’ ratings of ICL were significantly lower with the use of CLT compliant instructional materials compared to CLT non-compliant materials. This experiment showed that CLT compliant materials successfully lowered the perception of ICL for anxious learners. Finally, consistent with findings from Experiments 1 and 2, high maths anxiety significantly increased participants’ perception of the ICL associated with a task.

**Germaine Cognitive Load**

This research investigated whether high anxiety impacted participants’ subjective rating of GCL, and also if this differed with the use of CLT compliant materials compared to CLT non-compliant materials. These findings suggest high anxiety impacted the germane cognitive load of tasks of low and high element interactivity when using CLT compliant materials. These findings showed for highly anxious participants, the reported subjective ratings of GCL were significantly higher when using CLT compliant instructional materials compared to CLT non-compliant materials (refer to Section 6.4.3.2). When using CLT compliant materials, GCL ratings were significantly higher at high element interactivity compared to low element interactivity (refer to Table 6.11).
The greater investment of cognitive resources allocated to a task of increased complexity by participants using CLT compliant materials only was in contrast to findings for participants using CLT non-compliant materials. The investment of germane resources to a task for participants using CLT non-compliant materials was lower for tasks of high element interactivity compared to tasks of low element interactivity (refer to Figure 6.7). Highly anxious learners continued to invest germane cognitive resources for tasks of high element only when provided with the learning support of CLT compliant materials. Under conditions of high element interactivity, the CCHA group reported a significantly greater investment of germane resources compared to all other groups. These findings suggest CLT compliant materials supported highly anxious learners by promoting the investment of germane resources for both simple and complex tasks.

Germane cognitive load is the load relevant to learning and refers to the allocation of germane resources to a task. CLT compliant materials increased the investment of germane resources, or more accurately, “self-perceived learning” (Bergman et al., 2015; Hadie & Yusoff, 2016). The provision of worked examples may have indicated to participants the escalating complexity of a task and therefore the necessity to invest more resources to completion of the task. Furthermore, the CLT compliant instructional materials provided the learning support to highly anxious participants to successfully complete the task. As for Experiments 1 and 2, there was a significant correlation between participants’ ratings of GCL and task importance. Furthermore, at high element interactivity, high anxiety participants that used CLT compliant materials (CCHA group) also reported significantly higher ratings of task importance and task satisfaction compared to those that used CLT non-compliant materials (CNHA group) (refer to Section 6.4.3.3.3). This strengthened the likelihood of these participants to invest germane resources in a task.

6.5.6 Perceived task Anxiety Ratings

Exploratory question 2 was: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with
high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

This research examined whether participants with high maths anxiety that used CLT compliant instructional materials (CCHA group) reported lower perceived task anxiety than participants with high maths anxiety that used CLT non-compliant instructional materials (CNHA group) when solving problems of high element interactivity. The perceived task anxiety ratings of the CCHA group were significantly lower than the perceived task anxiety ratings of the CNHA group at high element interactivity. As for Experiments 1 and 2, these findings showed tasks of higher element interactivity resulted in corresponding higher levels of task anxiety (refer to Table 6.12). Higher levels of element interactivity were associated with significantly higher perceived task anxiety when using both CLT compliant materials and CLT non-compliant materials. Perceived task anxiety was greatest for those with high baseline maths anxiety in both conditions. CCLA group had the lowest perceived task anxiety at high element interactivity compared to all other groups, and this effect was significant at high element interactivity. The difference in perceived task anxiety ratings for low anxiety participants in the CLT compliant condition (CCLA) and the CLT non-compliant condition (CNLA) was not significant.

Whilst there was no significant difference in the baseline maths anxiety scores between the CLT compliant condition and the CLT non-compliant condition, there was a significant difference in the perceived task anxiety ratings of the CCHA and CNHA groups. The CLT non-compliant high anxiety group (CNHA group) experienced significantly higher perceived task anxiety levels than the CLT compliant high anxiety group (CCHA) when solving problems of high element interactivity. This confirmed that CLT compliant materials may provide support to highly anxious learners when solving complex problems. The use of CLT non-compliant materials may have intensified the perceived task anxiety experienced by highly anxious participants and contributed to the already elevated anxiety of these participants when completing complex tasks.
6.5.7 High Anxiety and Cognitive Load of Tasks with Low Element Interactivity

Research Question 5 was: When solving problems low in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

It was predicted when solving mathematics problems low in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials would achieve higher performance scores and report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. This is due to CLT compliant instructional materials providing learning support when WM resources are expended by anxiety (Hypothesis 6). These findings show the CCHA group achieved significantly higher performance scores and reported significantly lower mental effort ratings, resulting in significantly higher instructional efficiency scores, compared to the CNHA group.

Previous research has found cognitive load effects, such as the worked example effect, not relevant for tasks of low element interactivity (Chen et al., 2015; Leahy & Sweller, 2005; Sweller, 2010; Sweller & Chandler, 1994). This was due to sufficient working memory resources being available to deal with CLT non-compliant instructional design when tasks were simple. However, for highly anxious learners, it was posited that CLT compliant materials may be have been useful even for simple tasks. High anxiety resulted in working memory being severely compromised due to resources being allocated to tasks not relevant to learning. These results suggest that CLT compliant materials were of benefit to those with high maths anxiety for tasks of low element interactivity and the provision of CLT compliant instructional materials was able to significantly support learning when solving simple tasks. This was an important finding given previous research has not considered the potential importance of instructional materials designed according to the principles of cognitive load theory for tasks of low element interactivity. When considering affective aspects of the learner, in this case
anxiety, the limitations of working memory became apparent when solving even simple tasks, and therefore, effective instructional design was imperative to successful learning.

These results indicated for highly anxious learners, CLT compliant instructions resulted in significantly higher performance scores compared to CLT non-compliant materials when solving problems (refer to Section 6.4.3.1). The mental effort rating (Paas, 1992) for the CLT non-compliant high anxiety group (CNHA group) was significantly higher than the CLT compliant high anxiety group (CCHA group) when solving maths problems of low element interactivity (refer to Section 6.4.3.2.1). These results collectively resulted in significantly greater instructional efficiency for the CCHA group compared to the CNHA group for tasks of low element interactivity. From subjective ratings using the CLDS (Leppink et al., 2013), the CCHA group reported significantly lower ICL (refer to Table 6.10), lower ECL (refer to Table 6.9) and higher GCL (refer to Table 6.11) when completing tasks of low element interactivity compared to the CNHA group. These findings support Hypothesis 6.

6.5.8 Summary of Results

Results confirmed all of the proposed hypotheses. Support of these hypotheses indicated a relationship between learner anxiety, cognitive load and instructional design for tasks of both low and high of element interactivity.

Results showed that high element interactivity, high learner anxiety and CLT non-compliant instructional materials had a significant negative impact on performance, cognitive load and perceived task anxiety. This experiment found that the use of CLT compliant instructional materials significantly improved performance scores at high element interactivity for high anxiety learners. Similarly, for tasks of high element interactivity, the CCHA group reported significantly lower mental effort ratings compared to the CNHA group. These subjective ratings of mental effort were lower for the CCHA group despite reporting greater task completion times. The additional time spent on task by these participants suggested the effective use of the instructional materials containing worked examples, and as a result, reported significantly lower task difficulty ratings and experienced significantly higher instructional efficiency scores.
The use of CLT compliant instructional materials therefore supported learning for highly anxious participants. For highly anxious learners, the use of CLT compliant instructional materials significantly reduced ICL, reduced ECL (close to significant) and significantly increased GCL compared to the use of CLT non-compliant instructional materials when completing complex tasks. Importantly, the investment of germane resources was maintained at high element interactivity when using CLT compliant instructional materials, whereas this was significantly reduced when using CLT non-compliant materials. Higher subjective ratings of GCL for the CCHA group were accompanied by significantly higher ratings of task importance and task satisfaction compared to the CNHA group.

The use of CLT compliant instructional materials significantly reduced perceived task anxiety ratings of high anxiety learners. The increase in perceived task anxiety for problems of high element interactivity compared to problems of low element interactivity was greater for the CNHA than for the CCHA group. The additional anxiety experienced by these participants could be attributed to the use of CLT non-compliant materials, as there was no significant difference in baseline maths anxiety levels of these groups. This suggested the use of CLT compliant materials was important for highly anxious learners when solving problems of high element interactivity.

Finally, results also showed that given the reduced working memory capacity induced by high anxiety, CLT compliant instructional materials were also beneficial for high anxiety learners when solving problems of low element interactivity. The CCHA group had significantly higher performance scores and reported significantly lower ratings of mental effort and ICL ratings compared to the CNHA group for tasks of low element interactivity. CLT compliant instructional materials resulted in superior efficiency for learners with high anxiety for problems of low element interactivity. This finding that showed that CLT compliant instructional materials were effective for highly anxious students when completing problems of low element interactivity. This has not been previously found in cognitive load theory research.
6.6 LIMITATIONS

This experiment addressed limitations identified in Experiment 1 and Experiment 2. Significant results were attained for each of the research questions, supporting all hypotheses proposed. Limitations associated with variations in baseline anxiety levels between groups, small sample sizes, familiarisation with the effective use of worked examples in instruction, variation in expertise affecting levels of element interactivity of tasks and usefulness of worked examples (expertise reversal effect) and a clear distinction between instructional materials in the two conditions were all addressed.

6.7 CONCLUSION

These results showed that higher levels of element interactivity resulted in lower performance scores, higher ratings of cognitive load and higher ratings of perceived task anxiety. It is essential, therefore, that when learners are solving complex tasks, strategies are implemented to simplify these problems. This is especially true for learners with high maths anxiety, whose performance, and experience of cognitive load and perceived task anxiety is exacerbated by their maths anxiety. This experiment found that CLT compliant instructional materials provided relief for these learners.

Experiment 3 was again conducted using participants currently engaged in secondary education. High maths anxiety was identified as having a significant negative impact on student performance, cognitive load and task-related anxiety. It has been thought the anxiety levels of teachers may influence the anxiety experienced by students in maths learning environments (Beilock, et al., 2010; Brown, et al., 2008). Having established a negative relationship between anxiety and cognitive load in both secondary and tertiary education settings, further investigation into the impact of teacher anxiety on student anxiety and effective instruction would be worthwhile.
7 DISCUSSION

7.1 INTRODUCTION

This thesis comprised three experiments that examined whether instructional materials designed in accordance with cognitive load theory, primarily the provision of worked examples, provided learning support to students with high maths anxiety. Previous research on cognitive load theory has predominantly focussed on empirical studies that have predominantly focused on the effective design of instructional materials based on human cognitive architecture. The research conducted in this study investigated how affective aspects of the learner, such as anxiety, in conjunction with the design of mathematical instructional materials, impacts the cognitive load associated with a learning task.

This study intended to investigate the relevance of CLT in a novel context, that is, the application of materials designed in accordance with CLT as a means of support for highly anxious learners. The purpose of this research was to investigate whether the inclusion of worked examples in instructional materials would support learning of highly anxious learners in both secondary and tertiary education settings. The specific aims of the research were to investigate a potential relationship between learner anxiety and cognitive load theory and consequently examine whether worked examples, previously shown to reduce the cognitive load associated with a complex task, would reduce cognitive load and anxiety, and thereby improve maths performance for highly anxious learners when solving maths problems of high element interactivity. The support provided by instructional materials designed in accordance with cognitive load theory were investigated for tasks of high element interactivity (complex tasks), for highly anxious learners given the higher load that complex tasks place on working memory. Previous research confirms cognitive load effects for complex tasks only. However, highly anxious learners expend working memory resources on anxious thoughts not associated with a learning task. This consumes limited working memory resources and therefore, the value of worked examples for tasks of low element interactivity, simple tasks, was also examined in Experiment 3. Refinements in the
design of experimental materials and changes in subject groupings allowed more precise examination of the research questions and exploratory questions in Experiment 3.

The design of the three experiments was similar, first identifying participants’ baseline level of maths anxiety, and then having participants with low and high self-reported anxiety solve maths problems of varying levels of element interactivity using either CLT compliant instructional materials or CLT non-compliant instructional materials. Participants then completed a questionnaire concerning the cognitive load and anxiety associated with each task, as well as task difficulty, task engagement, task satisfaction and task importance. The content of the instructional materials for each experiment was aligned with the participants’ mathematics ability. Experiments 1 and 2 were similar in design but had different participant cohorts, and tasks completed by participants therefore varied accordingly. Experiment 1 was conducted in a secondary school setting, whilst Experiment 2 was conducted with students enrolled in tertiary maths education. In Experiments 1 and 2, participants completed 5 questions each of low, moderate and high element interactivity. Participants in the CLT compliant condition were provided with paired process-oriented worked examples, whilst those in the CLT non-compliant condition were provided with only a separate sheet of product-oriented worked examples.

Findings from Experiment 1 and 2 suggested greater differentiation between instructional materials in each of the conditions was required. Consequently, the instructional materials were revised for Experiment 3 and consisted of 10 questions each of low and high element interactivity only. The inclusion of tasks of moderate element interactivity in Experiments 1 and 2 did not notably add to the findings for these experiments. In addition, more robust representation of the CLT compliant condition and CLT non-compliant condition necessitated instructional materials for the CLT non-compliant condition to be amended with the provision of conventional problems to solve without any support from worked examples. As for Experiments 1 and 2, the CLT compliant condition received process-oriented worked examples. Experiment 3 was conducted in a secondary school setting.
Experiments 1 and 2 were guided by the same 4 research questions and 2 exploratory questions. Experiment 3 included an additional research question 5 (RQ₅) and associated hypothesis (H₆). The additional investigation in Experiment 3 was related to the impact of anxiety on performance and cognitive load for tasks of low element interactivity. This was undertaken as a result of significant findings for tasks of high element interactivity. The research questions and the exploratory research questions being investigated were as follows:

RQ₁: When solving mathematics problems high in element interactivity, do learners presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners presented with CLT non-compliant instructional materials?

RQ₂: Do learners with high baseline mathematics anxiety report higher cognitive load than learners with low baseline mathematics anxiety when solving problems of low, moderate and high element interactivity?

RQ₃: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

RQ₄: When solving mathematics problems high in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

RQ₅: When solving problems low in element interactivity, do learners with high baseline mathematics anxiety presented with CLT compliant instructional materials achieve higher performance scores and report lower cognitive load than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?
EQ1: When solving mathematics problems high in element interactivity, does the perceived intrinsic cognitive load and germane cognitive load differ for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials?

EQ2: When solving mathematics problems high in element interactivity, do learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials?

Results for each of the experiments (Section 7.2) and a summary of the key findings for the research (Section 7.3) are summarised below.

7.2 SUMMARY OF RESULTS

7.2.1 Summary of Results for Research Questions

Table 7.1 summarises the results for the Research Questions and associated alternative hypotheses in Experiments 1, 2 and 3.
Table 7.1

*Summary of Findings: Research Questions and Hypotheses for Experiments 1, 2 and 3*

<table>
<thead>
<tr>
<th>Research Questions and Hypotheses</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RQ_{1A}: Performance</strong></td>
<td>No (no significant difference)</td>
<td>No (no significant difference)</td>
<td>Yes</td>
</tr>
<tr>
<td>CLT compliant &gt; CLT non-compliant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RQ_{1B}: Extraneous Cognitive Load</strong></td>
<td>No (no significant difference)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CLT compliant &lt; CLT non-compliant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H_1: Performance</strong></td>
<td>Not confirmed</td>
<td>Not confirmed</td>
<td>Confirmed</td>
</tr>
<tr>
<td>CLT compliant &gt; CLT non-compliant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H_2: Extraneous Cognitive Load</strong></td>
<td>Not confirmed</td>
<td>Not confirmed</td>
<td>Confirmed</td>
</tr>
<tr>
<td>CLT compliant &lt; CLT non-compliant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RQ_2: Cognitive Load</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>High Anxiety &gt; Low Anxiety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H_3: Cognitive Load</strong></td>
<td>Confirmed</td>
<td>Confirmed</td>
<td>Confirmed</td>
</tr>
<tr>
<td>High Anxiety &gt; Low Anxiety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RQ_3: Performance</strong> (High EI)</td>
<td>No (no significant difference)</td>
<td>No (no significant difference)</td>
<td>Yes</td>
</tr>
<tr>
<td>CCHA &gt; CNHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H_4: Performance</strong> (High EI)</td>
<td>Not confirmed</td>
<td>Not confirmed</td>
<td>Confirmed</td>
</tr>
<tr>
<td>CCHA &gt; CNHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RQ_4: Extraneous Cognitive Load</strong> (High EI)</td>
<td>No (no significant difference)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CCHA &lt; CNHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H_5: Extraneous Cognitive Load</strong> (High EI)</td>
<td>Not confirmed</td>
<td>Not confirmed</td>
<td>Confirmed</td>
</tr>
<tr>
<td>CCHA &lt; CNHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQ5A: Performance (Low EI)</td>
<td>CCHA &gt; CNHA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>H6A: Performance (Low EI)</td>
<td>CCHA &gt; CNHA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>RQ5b: Extraneous Cognitive Load (Low EI)</td>
<td>CCHA &lt; CNHA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>H6b: Extraneous Cognitive Load (Low EI)</td>
<td>CCHA &lt; CNHA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note. CCHA – CLT compliant high anxiety group; CNHA – CLT non-compliant high anxiety group

Table 7.1 shows findings from Experiments 1 and 2 confirmed a negative relationship between anxiety and cognitive load. However, this was the only hypothesis confirmed in Experiments 1 and 2. Conversely, findings from Experiment 3 confirmed all of the proposed hypotheses. These results showed for highly anxious learners, the provision of instructional materials designed according to the principles of CLT improved performance and reduced cognitive load when solving both simple and complex algebra problems.

The following identifies some points to note regarding the limitations of Experiments 1 and 2 are as follows. Experiment 1 had participants with significantly higher baseline anxiety ratings in the CLT compliant condition indicating any working memory support provided by the materials may have been nullified by the impact of high anxiety on the working memory of participants in this condition. Instructional materials used in the CLT non-compliant condition in Experiments 1 and 2 were considered to provide some support for participants and therefore not create sufficient differentiation from materials used in the CLT compliant condition. Limited variation between the instructional materials used in the two conditions may have contributed to non-significant findings for Experiments 1 and 2. These limitations were addressed in Experiment 3. Experiment
3 ensured baseline anxiety measures of participants in each condition were not significantly different and the instructional materials provided to each condition were sufficiently distinct in terms of learning support and compliance with cognitive load theory. Experiment 3 provided the most noteworthy findings. These findings are explained more fully below.

7.2.1.1 Performance and Cognitive Load using CLT compliant instructional materials (RQ1: H₁ and H₂)

Research question 1, and associated hypotheses 1 and 2, proposed when solving mathematics problems high in element interactivity, participants presented with CLT compliant instructional materials will outperform and report lower cognitive load than participants presented with CLT non-compliant instructional materials. Due to limitations regarding instructional materials and homogeneous grouping of participants in terms of anxiety associated with Experiment 1 and 2, Hypotheses 1 and 2 were confirmed only in Experiment 3. Findings for Experiment 3 indicated the inclusion of worked examples in instructional materials improved performance scores and reduced extraneous cognitive load for complex tasks. This confirmed previous research that CLT compliant instructions support learning when element interactivity is high (Leahy & Sweller, 2005; Paas et al., 2003b; Sweller, 2010; Sweller & Chandler, 1994).

7.2.1.2 Relationship between cognitive load and maths anxiety (RQ2: H₃)

Research question 2, and associated hypothesis 3, proposed participants with high baseline mathematics anxiety will report higher cognitive load than participants with low baseline mathematics anxiety due to a higher load imposed on working memory caused by anxiety. All three experiments confirmed Hypothesis 3 with findings supporting a significant relationship between anxiety and cognitive load. In all 3 experiments, a significant positive correlation was found between anxiety and mental effort, measured using the Cognitive Load Subjective Rating Scale (Paas, 1992). In Experiments 1 and 2, a significant positive correlation was found between anxiety and ECL, measured using the Cognitive Load Differentiating Scale (Leppink et al., 2013). This load, measured as either mental effort or extraneous cognitive load (ECL), was not
alleviated by the use of CLT compliant materials, as per the results in Experiment 1 and 2. This suggests that the additional CLT compliant instructional materials might have been a burden for highly anxious learners rather than a source of learning support. However, Experiment 3 showed participants with high anxiety using CLT compliant instructional materials reported significantly lower mental effort ratings and significantly lower ratings of extraneous cognitive load compared to participants with high anxiety using CLT non-compliant instructional materials when solving tasks of high element interactivity. This suggests that the provision of worked examples did provide learning support to highly anxious learners when solving complex tasks.

7.2.1.3 Performance of high anxiety learners: High element interactivity (RQ$_3$: H$_4$)

Research question 3, and associated hypothesis 4, proposed when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will outperform participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. This was not confirmed in Experiments 1 and 2. Interestingly, the CLT compliant low anxiety group significantly outperformed all other groups suggesting perhaps the importance of the combination of both low anxiety and CLT compliant materials. This indicates that low anxiety and the provision of CLT compliant instructional materials is most conducive to optimising performance scores. In Experiments 1 and 2, the use of CLT compliant materials did not lead to improved performance scores for highly anxious learners. This suggested the additional materials provided might have been overwhelming for these participants when attempting to solve a complex problem. Findings for Experiment 3 showed that participants using CLT compliant materials outperformed participants using CLT non-compliant materials, and the CCHA group significantly outperformed the CNHA group. The result suggests CLT non-compliant materials adversely affected performance scores for participants with high anxiety.
7.2.1.4 ECL of high anxiety learners: High element interactivity (RQ4: H5)

Research question 4, and associated hypothesis 5, proposed when solving mathematics problems high in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. This hypothesis was not confirmed in Experiments 1 and 2. The use of CLT compliant materials did not lead to lower mental effort ratings for highly anxious learners. In all three experiments, high anxiety resulted in higher perceived mental effort ratings and interestingly, the CCLA group reported significantly lower mental effort ratings compared to all other groups. This again suggested the importance of the combination of both low anxiety and CLT compliant materials. However, in Experiment 1 and 2, the CNHA group reported a greater change in mental effort ratings when completing tasks of high element interactivity compared to moderate element interactivity compared to the CCHA. This indicated the use of CLT compliant materials became advantageous for highly anxious learners when solving complex tasks. Findings from Experiment 1 showed experts reported significantly lower cognitive load compared to novices and expertise significantly reduced mental effort ratings of highly anxious participants using CLT non-compliant materials. This suggests expertise may have been an important factor in overcoming the burden associated with high mental effort for learners with high maths anxiety. Findings from Experiment 2 showed that high anxiety resulted in higher ECL ratings and the use of CLT compliant materials did not significantly reduce these ratings. The results indicated a significant positive correlation between mental effort and task difficulty. The findings for Experiment 3 showed that participants in the CNHA group reported significantly higher ratings of perceived task difficulty compared to the CCHA group.

The reported ECL in Experiments 1 and 2 indicated the use of worked examples added to the extraneous cognitive load of a task for highly anxious learners. This could be attributed to the higher baseline anxiety of the participants in the CLT compliant condition and insufficient differentiation between the instructional materials in the two conditions, respectively. However, in Experiment 3, the CLT compliant high anxiety group reported significantly lower mental effort ratings, and consequently significantly
higher efficiency scores compared to the CLT non-compliant high anxiety group. Hypothesis 5 was therefore confirmed in Experiment 3.

7.2.1.5 Performance and Cognitive Load of high anxiety learners: Low element interactivity (RQ5: H6)

Experiment 3 found that CLT compliant materials provided learning support for highly anxious participants when solving problems of high element interactivity (see Section 7.2.1.3 and Section 7.2.1.4). These findings showed that for highly anxious learners, performance scores were higher and cognitive load ratings were lower when using CLT compliant instructional materials compared to CLT non-compliant instructional materials. Consequently, the potential benefit of the provision of worked examples was also investigated for tasks of low element interactivity. Research question 5, and associated hypothesis 6, proposed when solving mathematics problems low in element interactivity, participants with high baseline mathematics anxiety presented with CLT compliant instructional materials will achieve higher performance scores and report lower cognitive load than participants with high baseline mathematics anxiety presented with CLT non-compliant instructional materials. Participants with high anxiety reported significantly lower mental effort rating, ECL ratings and ICL ratings when using CLT compliant materials compared to participants using CLT non-compliant materials for tasks of low element interactivity. In addition, those using CLT compliant materials also performed significantly better, resulting in significantly greater efficiency scores than those using CLT non-compliant materials for tasks of low element interactivity. This result confirmed Hypothesis 6.

7.2.2 Summary of Results for Exploratory Questions

Table 7.2 summarises the results for the Exploratory Questions in Experiments 1, 2 and 3. These findings are explained more fully below.
Table 7.2

Summary of Findings: Exploratory Questions for Experiments 1, 2 and 3

<table>
<thead>
<tr>
<th>Exploratory Question</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EQ1A: Intrinsic Cognitive Load:</strong> Difference between CCHA and CNHA</td>
<td>Yes CCHA &gt; CNHA</td>
<td>Yes CCHA &gt; CNHA HA &gt; LA</td>
<td>Yes CCHA &lt; CNHA</td>
</tr>
<tr>
<td><strong>EQ1B: Germane Cognitive Load:</strong> Difference between CCHA and CNHA</td>
<td>Yes CCHA &lt; CNHA HA &gt; LA</td>
<td>Yes CCHA &lt; CNHA</td>
<td>Yes CCHA &gt; CNHA</td>
</tr>
<tr>
<td><strong>EQ2: Task Anxiety:</strong> Difference between CCHA and CNHA</td>
<td>No CCHA &gt; CNHA</td>
<td>No CCHA &gt; CNHA</td>
<td>Yes CCHA &lt; CNHA</td>
</tr>
</tbody>
</table>

*Note.* CCHA – CLT compliant high anxiety group; CNHA – CLT non-compliant high anxiety group

### 7.2.2.1 Intrinsic Cognitive Load of high anxiety learners (EQ1A)

Exploratory Question 1 investigated whether the perceived intrinsic cognitive load differed for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials when solving problems of high element interactivity. This was an exploratory investigation due to the absence of previous relevant research investigating the relationship between intrinsic cognitive load and anxiety. The intrinsic cognitive load of a task was higher at higher levels of element interactivity. This was expected as ICL is directly related to the level of element interactivity involved in a task. This finding confirmed that the experimental instructional materials successfully differentiated between tasks of varying levels of element interactivity. An interesting finding was that participants with high maths anxiety reported higher ratings of perceived intrinsic cognitive load compared to low anxiety participants for complex tasks in all experiments, regardless of the instructional condition. This difference was significant in Experiment 2 and 3. Of further interest, in Experiment 3, the use of CLT compliant instructional materials by highly anxious learners led to lower subjective ratings of ICL.
The CNHA group reported significantly higher ratings of ICL compared to the CCHA group for tasks of low and high element interactivity. These findings are discussed further in Section 7.3.2.3

7.2.2.2 Germane Cognitive Load of high anxiety learners (EQ1b)

Exploratory Question 1 also investigated whether the perceived germane cognitive load differed for high anxiety learners presented with CLT compliant instructional materials compared to high anxiety learners presented with CLT non-compliant instructional materials when solving problems of high element interactivity. This was an exploratory investigation due to the absence of previous relevant research investigating the relationship between germane cognitive load and anxiety. In Experiments 1 and 2, there was no significant difference in ratings of germane cognitive load for participants in the CCHA compared to the CNHA group. However, findings from Experiment 1 suggested that participants with high anxiety using CLT compliant materials continued to invest germane resources when solving more complex tasks, in contrast to those using CLT non-compliant materials. Participants in the CNHA group reported they invested significantly less germane resources for tasks of high element interactivity compared to tasks of moderate element interactivity. This finding suggests that without the provision of CLT compliant instructional materials and the learning support provided by them, participants with high anxiety did not have sufficient working memory resources available to invest germane resources when a task was complex. In both Experiment 1 and 2, the GCL ratings for participants in the CNLA group were significantly lower than all other groups. Experiment 3 findings showed participants using CLT compliant instructional materials reported significantly higher ratings of germane cognitive load compared to participants using CLT non-compliant instructional materials. The CCHA group reported the highest GCL ratings compared to all other groups for tasks of low and high element interactivity. As in experiments 1 and 2, when completing tasks of high element interactivity, participants using CLT non-compliant materials did not report significantly higher ratings of GCL whilst completing tasks of high element interactivity compared to when they were completing tasks of low element interactivity. In all three experiments, there was a significant positive correlation between germane...
cognitive load and participants’ subjective rating of the level of task importance (and between GCL and participants’ subjective rating of task satisfaction in Experiment 3).

7.2.2.3 Task Anxiety of high anxiety learners (EQ2)

Exploratory Question 2 investigated whether learners with high mathematics baseline anxiety presented with CLT compliant instructional materials report lower perceived task anxiety than learners with high baseline mathematics anxiety presented with CLT non-compliant instructional materials when solving mathematics problems high in element interactivity. This was an exploratory question due to an absence of previous CLT research to allow determination of a hypothesis related to the effect of using CLT compliant materials on task anxiety. In Experiment 1 and 2 there was no significant difference in perceived task anxiety between the CCHA group and the CNHA group. It is worth noting that in Experiment 1, the baseline maths anxiety of participants in the CLT compliant condition was significantly higher than the baseline maths anxiety of participants in the CLT non-compliant condition. Despite this, there was no significant difference in the perceived task anxiety between the two conditions for high anxiety participants suggesting the CLT compliant instructional materials may have successfully alleviated anxiety for these participants. Furthermore, when completing tasks of high element interactivity compared to moderate element interactivity, high anxiety participants reported higher perceived task anxiety when using CLT non-compliant materials compared to those using CLT compliant materials. In addition, findings from Experiments 1 and 2 showed novices reported significantly higher perceived task anxiety compared to experts. This again suggests the importance of expertise in overcoming maths anxiety.

All three experiments showed that participants reported higher perceived task anxiety was greater for tasks of high element interactivity compared to tasks of low element interactivity. However, only findings from Experiment 3 confirmed significantly lower ratings of perceived task anxiety for highly anxious learners using CLT compliant materials compared to CLT non-compliant materials. For tasks of high element interactivity, there was no significant difference between the perceived task anxiety ratings of low and high anxiety participants using CLT compliant materials. Participants
identified as highly anxious had a significantly higher baseline anxiety compared with participants identified as low anxiety. However, highly anxious participants did not report significantly higher perceived task anxiety compared with low anxiety participants. These results suggested CLT compliant instructional materials alleviated the anxiety experienced by highly anxious learners when solving complex tasks.

7.3 SUMMARY OF KEY FINDINGS

The results of this research indicate three overall key findings. Firstly, a relationship has been shown to exist between cognitive load and maths anxiety. Secondly, instructional materials designed according to the principles of cognitive load theory were shown to improve performance, and reduce the extraneous cognitive load and intrinsic cognitive load for highly anxious learners when solving complex maths problems. Furthermore, the use of CLT compliant instructional materials enabled highly anxious learners to invest more germane resources in a task. In addition, CLT compliant instructional materials reduced the anxiety associated with solving maths problems for highly anxious learners. Thirdly, instructional materials designed according to the principles of cognitive load theory also provided learning support for highly anxious learners when completing simple tasks.

A discussion of these key findings in more detail is provided in the following section.

7.3.1 Relationship between Cognitive Load and Maths Anxiety

The results of the three studies show that there is a relationship between anxiety and the cognitive load associated with a complex task (see Section 7.2.1.2 for a summary of these results). Participants with high maths anxiety reported higher cognitive load than participants with low maths anxiety when using both the cognitive load subjective rating scale and the cognitive load differentiating scale. This finding confirmed that for highly anxious learners, solving maths problems imposed cognitive load in addition to that associated with the maths task alone. “Working memory resources are compromised whenever the anxiety is aroused” (Ashcraft & Krause, 2007, p. 247) due to the “consumption of working memory resources” (Hunt, 2011, p. 129) by interfering
task-irrelevant thoughts. Maths anxiety therefore generates in an increase in the cognitive load associated with a maths task for highly anxious learners.

7.3.2 CLT Compliant Materials Instructional Materials Provided Working Memory Support For Anxious Learners

7.3.2.1 Performance

This research showed that when completing tasks of high element interactivity, participants using CLT compliant instructional materials outperformed participants using CLT non-compliant instructional materials (See section 7.2.1.3). This result confirmed previous research that CLT compliant instructions support learning for tasks of high element interactivity (Leahy & Sweller, 2005; Sweller, 2010; Sweller & Chandler, 1994). Investigation of performance scores when considering participants baseline maths anxiety showed the need for instructional materials to be designed in accordance with the principles of CLT was of particular importance for highly anxious learners. The learning support offered by the provision of worked examples enabled significantly improved performance as a result of significantly reducing the cognitive load associated with tasks of high element interactivity. Furthermore, results confirmed previous findings that for tasks of high element interactivity that place greater demands on working memory, “adverse effects of anxiety on task performance generally become stronger”. (Hunt, 2011, p130). For those using CLT non-compliant instructional materials, the complexity of the learning task and poor instructional design may have been detrimental to performance, and may have contributed to additional anxiety experienced by an already highly anxious individual. These findings also suggested a key factor in supporting learners with high anxiety was the fostering of expertise. The impact of anxiety on performance and perception of cognitive load, and moreover, maths anxiety itself, was consistently lower for experts compared to novices. This finding also aligned with previous research that suggests the greater need for the provision of worked examples for novices (van Gog et al., 2006; van Merriënboer, 1997). The need for this learning support diminishes as learners gain expertise within a domain (Clark et al., 2006; Renkl & Atkinson, 2003).
7.3.2.2 Extraneous Cognitive Load

Findings for extraneous cognitive load confirmed previous research that suggests the use of worked examples reduced the extraneous cognitive load of a task (Paas et al., 2003b). Furthermore, CLT compliant instructional materials have been shown to be of additional importance for highly anxious learners (see Section 7.2.1.4). The extraneous cognitive load of a task was shown to be higher for learners with high maths anxiety, and this was alleviated for participants provided with CLT compliant instructional materials. Furthermore, this resulted in improved instructional efficiency for highly anxious participants using CLT compliant instructional materials. The learning support provided by the provision of worked examples effectively reduced the extraneous cognitive load of the task for highly anxious learners.

7.3.2.3 Perception of Intrinsic Cognitive Load

Intrinsic cognitive load is considered to be constant for any learner (of similar expertise) completing the same task (Paas, 2003b). Intrinsic cognitive load is directly related to the level of element interactivity of a task, and is independent of instructional design (Sweller, 2010). One would therefore expect the intrinsic cognitive load of a task to be the same for all learners, provided their domain specific expertise was the same. However, this study showed that there were differences in the perceived intrinsic cognitive load of participants with high anxiety compared to participants with low anxiety. This suggests that affective aspects of learning, such as anxiety, created differences in the perception of the inherent complexity of a problem. Highly anxious learners consistently perceived the intrinsic cognitive load of a task to be higher (see Section 7.2.2.1). This is an important finding of the research, consistent with findings of Naismith et al. (2015), which compared various measures of intrinsic cognitive load. It shows that “high levels of negative emotions were directly related to increased perceptions of intrinsic task difficulty and complexity” (Naismith et al., 2015, p. 812). Importantly, it was the subjective nature of load that was reported and the inherent load associated with a task was anticipated to be greater when learners were highly anxious. Consequently, if highly anxious learners perceived a task to be of greater difficulty,
there was greater necessity for learning support. From a theoretical perspective, this was a key finding across all three experiments in this thesis.

7.3.2.4 Investment Of Germane Resources

The use of CLT compliant instructional materials resulted in the investment of germane resources for participants with high anxiety. As a result of the load imposed on working memory by anxiety, the investment of germane resources by anxious learners was compromised. However, these findings suggest highly anxious learners were able to invest germane resources when using CLT compliant instructional materials (see section 7.2.2.2 for a summary of these results). This was a key theoretical finding across all three experiments in this thesis. Results of all three experiments consistently showed the use of CLT non-compliant materials was detrimental to the investment of germane resources. Furthermore, participants consistently reported similar, and even lower, GCL for complex problems compared to simple problems. The provision of worked examples may have indicated to learners the escalating complexity of each task and therefore encouraged the learner to invest more resources to successfully complete the task. This explanation would support the reclassification of this measure of germane cognitive load being indicative of “self-perceived learning” (Bergman et al., 2015). The additional allocation of cognitive resources could also be attributed to the availability of germane resources as a result of the learning support provided with the use of CLT materials. Despite anxious thoughts contributing to load not relevant to learning, additional working memory resources made available due to the use of CLT compliant instructional materials may be used for task relevant activities imposing a germane load. The investment of germane resources corresponded with participants considering a task to be of greater importance. When students fail to assign germane resources to a task, either because of the load associated with a task, perceived lack of importance of a task or anxiety levels, performance is adversely affected.

7.3.2.5 Task Anxiety

Research by Faust, Ashcraft & Fleck (1996) confirmed “an overall anxiety-complexity effect” (p. 28) which suggests the deleterious effects of anxiety become more evident as
task difficulty, or complexity, increases. These findings supported this premise with regards to mathematics. Importantly, findings from this research showed that CLT compliant instructional materials not only supported anxious learners, but also reduced the level of anxiety experienced by anxious learners whilst completing maths tasks (see Section 7.2.2.3 for a summary of these results). This research supported similar findings in recent research that investigated the impact of negative emotions on a learner’s cognitive load. For example, when learners experience a sense of confusion (Arguel et al., 2017) or pain (Smith & Ayres, 2014a), working memory is compromised. Furthermore, the learning support provided by CLT compliant instructional materials may diminish the negative emotion experienced (Pawar et al., 2017; Young et al., 2014). Findings of the research presented here showed that when completing maths tasks of high element interactivity, the use of CLT compliant instructional materials effectively reduced the associated anxiety experienced. Conversely, the use of CLT non-compliant instructional materials may be considered to have contributed further to the anxiety of already highly anxious learner.

7.3.3 CLT Effects Evident For Highly Anxious Learners Solving Tasks Of Low Element Interactivity

It was confirmed that participants with high maths anxiety that used CLT compliant instructional materials experienced lower cognitive load than participants with high maths anxiety that used CLT non-compliant instructional materials on mathematics tasks of low element interactivity. This may have been due to CLT compliant materials providing support when working memory resources were consumed by anxiety (see section 7.2.1.5). Previous CLT research found cognitive load effects, such as the worked example effect, not relevant for tasks of low element interactivity (Chen et al., 2015; Leahy & Sweller, 2005; Sweller, 1994; Sweller, 2010; Sweller & Chandler, 1994). This was due to sufficient working memory resources being available to deal with CLT non-compliant instructional design when tasks were simple. Only for complex tasks would limitations of working memory demand effective design of instructional materials to enhance learning. However, for highly anxious learners, it was posited that CLT compliant materials may be have been useful even for simple tasks, as working memory available for learning would have been compromised due to resources
being allocated to tasks not relevant to learning, that is, anxious thoughts. As a result, highly anxious learners would have less working memory resources available to invest in a learning task due to these resources being expended by anxiety. Furthermore, research suggests that during simple tasks, working memory resources of highly learners engage more freely in task-irrelevant thoughts (Vytal et al., 2013). Findings from this research suggest that CLT compliant materials were beneficial to those with high maths anxiety for tasks of low element interactivity and were able to significantly support learning. The research showed that highly anxious learners performed better and reported a reduced cognitive load for tasks of low element interactivity when using CLT compliant materials. This indicated that cognitive load effects, such as the worked example effect, may be relevant for simple tasks for highly anxious learners.

7.4 LIMITATIONS OF CURRENT RESEARCH

There were a number of limitations in Experiments 1 and 2 that were addressed in Experiment 3. Limitations associated with this research were addressed as the study progressed across the three experiments. Limitations included inconsistency in the baseline anxiety levels of participants in each instructional condition (participants using CLT compliant instructional materials had higher baseline maths anxiety) and small sample size (Experiment 1). Strategies to ensure an even distribution of participants with low and high anxiety in each of the instructional conditions were implemented in Experiment 2 and 3. Experiment 3 had fewer participants than Experiment 2 and allocation into the instructional conditions was stratified following determination of participant’s maths anxiety in a prior session.

In Experiments 1 and 2, the distinction between the CLT compliant instructional materials and CLT non-compliant instructional materials needed to be refined. Attempts to create more variation between the two instructional conditions in each of the experiments so they provided more robust representations of CLT compliant and CLT non-compliant instructional materials meant the instructional materials for each experiment were different. This was also necessary as a result of different contexts for each experiment – using participants from secondary school enrolled in Stage 4 and
Stage 5 mathematics (Experiments 1 and 3) and participants enrolled in tertiary education (Experiment 2).

All experiments were conducted using algebra problems only, a specific content area within the domain of mathematics. This study examined mathematics anxiety for two principal reasons. Firstly, research has determined the mathematics discipline to be a considerable source of anxiety for learners (Hopko et al., 2003b). However, in order for these findings to be generalizable, similar findings would need to be replicated outside the domain of mathematics. In addition, an established instrument to measure mathematics anxiety currently exists, the Abbreviated Mathematics Anxiety Scale. This study used this instrument to measure participant’s level of maths anxiety. This self-report measure has been shown to be a valid and reliable tool for determining an individual’s level of maths anxiety (Hopko et al., 2003a). A further limitation for this study was the relative short duration of each experiment. However, participants had prior knowledge of the content covered in the experiments and consequently no pre-training was required. Therefore, the duration of each experiment was sufficient for participants to complete the necessary tasks and accompanying questionnaires. The research design was considered appropriate to investigate and establish the relationship between cognitive load theory and anxiety. Future research could be more extensive in terms of content and duration.

Finally, the current research had a between subjects design for each of the three experiments. The addition of a within subjects component may have allowed a comparison between CLT compliant and CLT non-compliant conditions on the performance and perceived cognitive load for the same participant.

7.5 THEORETICAL IMPLICATIONS FOR CLT

CLT research has not previously established a direct relationship between cognitive load and anxiety through the use of instructional materials based on CLT principles. This research has shown that affective factors, like anxiety, expend working memory resources and have a significant effect on the cognitive load associated with a task. Future CLT research needs to take this relationship into consideration. This could be
done by investigating the affective characteristics of the learner alongside the effectiveness of instructional design. Furthermore, the impact was not restricted to the extraneous cognitive load of a task. Use of the CLDS (Leppink et al., 2013), which measures the load associated with different types of cognitive load, showed anxiety affected the extraneous, intrinsic and germane cognitive load associated with a task, for highly anxious learners. Finally, the worked example effect was found to be evident for tasks of both low and high element interactivity for highly anxious learners, not only for complex tasks as previously shown in CLT research. This study provides evidence that CLT compliant instructional materials can support highly anxious learners when solving simple mathematics problems.

7.6 PRACTICAL IMPLICATIONS OF THE STUDY

A recent global study of 72 countries by the OECD found Australian students to suffer more anxiety than students in most other countries, with 70% of females and 53% of males stating they experience stress over school work (OECD, 2017). The outcome of the current research may form the basis of intervention techniques, in terms of instructional design, to reduce mathematics anxiety. The following provides further details regarding some practical strategies that may be employed.

7.6.1 Mathematics Instruction

Many learners experience anxiety when studying mathematics. At the outset, a learning environment that recognises the anxiety experienced by learners and the associated limitations placed on them is essential. This acknowledgement would then initiate attention to the development of effective instructional materials and teaching strategies for highly anxious learners. This would involve the following:

• Improving the performance of anxious students in mathematics by providing instructional materials with worked examples for simple and complex tasks;
• Reducing student anxiety through effective instructional design based on the principles of CLT, leading to improved performance;
• Maximising and maintaining student intrinsic motivation by alleviating maths anxiety linked to poor participation in mathematics, which may ultimately reduce attrition rates in mathematics;
• Providing students with strategies, such as those associated with worked examples, to assist in the efficient allocation of cognitive resources to a task to improve the effectiveness and efficiency of learning;
• Encouraging the pursuit of expertise as an effective way of overcoming anxiety in maths anxious students.

7.6.2 Teacher Anxiety

Interestingly, high baseline maths anxiety increased effort ratings at high element interactivity for novices in both conditions (using CLT compliant and CLT non-compliant materials) but for experts only when using CLT non-compliant materials. When using CLT compliant materials, high baseline maths anxiety did not result in higher effort ratings for experts compared to low baseline maths anxiety. The expertise of the learner allows them to maintain similar effort levels despite higher anxiety due to the support provided by CLT compliant materials. Participants in Experiment 2 of this thesis consisted of tertiary mathematics education students. It was established that maths anxiety was high for many of these students and this anxiety negatively impacted their maths performance and the cognitive load associated with maths tasks. Previous research has established that teacher anxiety exacerbates student anxiety during learning (Gresham, 2007). This emphasises the need for expertise amongst teachers within their domain in order to curtail their own anxiety, and subsequently, the anxiety of students, in the mathematics learning environment. In order to teach effectively, the development of sound maths skills and a positive attitude towards maths is essential (Beilock et al., 2010).

7.6.3 Summary of Practical Implications

In summary, this research suggests a need to find ways to encourage student motivation to learn and achieve in mathematics, with consideration given to the associated anxiety
experienced by many students. Learning support for highly anxious students may be best achieved by:

- Identification of most effective learning materials for highly anxious students, and for which tasks they are most appropriate, for example, the provision of CLT compliant instructional materials for both simple and complex tasks;
- Implementation of instructional materials designed according to the principles of cognitive load theory, for example, provision of worked examples in maths instruction;
- Ensuring teacher expertise so anxiety is not conveyed to students during instruction;
- Minimising the anxiety experienced by students learning mathematics as a result of these strategies in order to improve participation and performance in mathematics.

7.7 IDEAS FOR FUTURE RESEARCH

The findings of this research have implications for the design of instructional materials for highly anxious students. This research investigated the worked example effect, and future research could investigate other specific cognitive load effects in relation to highly anxious learners. This may lead to identification of further strategies that may be adopted in a mathematics-learning environment to address anxiety. These strategies may then be investigated in terms of applicability to disciplines outside the domain of mathematics. In addition, anxiety was shown to affect learner’s perception of cognitive load. Further investigation of the different types of cognitive load for highly anxious students would be worthwhile. This would include additional examination of the definition and measurement of germane cognitive load.

Additionally, this study briefly considered a number of other factors that may be of relevance to this body of research, such as task difficulty, task engagement, task importance and task satisfaction. The impact of anxiety on these variables, and in turn,
their impact on student performance and cognitive load, may lead to a more comprehensive understanding of effective learning support for highly anxious learners. Further investigation may involve longitudinal studies, or qualitative analysis concerning the sources of, or reasons for, maths anxiety. In addition, the directionality of the relationship between maths anxiety and poor performance has not been conclusively established. This may provide additional insight into the relationship between cognitive load theory and anxiety.

As with any self-report measures, there are issues surrounding the use of maths anxiety scales as a valid tool for measuring the level of maths anxiety an individual experiences. Therefore, it was important that an appropriate scale be implemented. (p221, Hunt, 2011). AMAS self-report measure has been shown to be a valid and reliable tool for determining an individual’s level of maths anxiety (Hopko et al., 2003a). However, greater support for these findings could be attained by replicating experiments using a variety of anxiety measures.

Beyond the scope of this thesis but of particular interest may be gender studies. Recent research suggests gender differences in information processing be added to current theoretical considerations regarding cognitive load (Bevilacqua, 2017). Furthermore, gender differences have been established in previous research on the subject of both mathematics (Buckley, 2016; Samuelson & Samuelson, 2016) and mathematics anxiety (Devine et al., 2012).

Further consideration of the level of expertise of participants would be useful in additional examination of results. Determination of a learner’s expertise may be considered essential, as this may influence the level of element interactivity, and therefore, the cognitive load of a task for a learner. That is, what is considered complex for a novice may in fact be a simple task for an expert. Furthermore, depending on a learner’s expertise, worked examples either may not be necessary for experts (known as the Expertise Reversal Effect) or may be overwhelming for novices (due to lack of prior knowledge), both of which contribute to load. In addition, expertise influences a learner’s anxiety, which in turn, influences a learner’s perception of the cognitive load of a task. In order to determine whether the provision of CLT compliant instructional
materials are able to consistently support learning for highly anxious learners, for both simple and complex tasks, further analysis in relation to expertise is important. In addition, given the implications of teacher anxiety on student engagement and success in mathematics, the expertise of pre-service and in-service teachers could be further investigated. Consequently, future research into the area of anxiety and cognitive load theory could look further at the impact of factors that affect anxiety, such as expertise.

7.8 CONCLUSION

This study confirmed a relationship between anxiety and cognitive load, that is, highly anxious learners reported greater cognitive load associated with maths tasks than low anxious learners. This occurred as a result of anxiety utilising working memory resources unconnected to the learning task. This study showed that the use of instructional materials designed in accordance with cognitive load theory can successfully reduce the cognitive load associated with a task for highly anxious students, and therefore improve performance. The use of CLT compliant instructional materials also reduced learner anxiety and encouraged the investment of germane resources to further enhance learning. In addition, CLT compliant materials were found to be beneficial to highly anxious learners for both simple and complex tasks. This is because the capacity of working memory is compromised by anxiety. The implications of these findings have relevance for both students and teachers who experience anxiety associated with a learning task. This research suggests there is a need for further investigation into affective influences on learning, such as academic-related anxiety. Instructional design must take into account limited working memory resources as this impacts the amount of information that can be processed simultaneously. This includes the appropriate and beneficial practice of the utilisation CLT compliant instructions. As such, CLT can play a key role in providing learning support and alleviating anxiety for highly anxious learners.
REFERENCES


Miller, G. A. (1956). The magical number seven plus or minus two: some limits on our capacity for processing information. Psychological Review, 63, 81-97.


REFERENCES EMERGING FROM THIS RESEARCH


APPENDIX A1

Ethics Approval Notification
Approval Letter after review in reply please quote: HE14/108

29 May 2014

Ms Deborah Chadwick
233 Rainbow St
Coogee NSW 2034

Dear Ms Chadwick,

Thank you for your response dated 28 May 2014 to the HREC review of the application detailed below. I am pleased to advise that the application has been approved.

Ethics Number: HE14/108
Project Title: Providing Working Memory (WM) Support for Anxious Students using Cognitive Load Theory Compliant Instructions
Researchers: Ms Deborah Chadwick, Dr Shirley Agostinho, Dr Sharon Tindall-Ford
Approval Date: 29 May 2014
Expiry Date: 28 May 2015

The University of Wollongong/Illawarra Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/human/index.html. This report must be completed, signed by the appropriate Head of School, and returned to the Research Services Office prior to the expiry date.

As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date. If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely

Professor Kathleen Clapham

Chair, Social Sciences Human Research Ethics Committee
APPENDIX A2

Ethics Approval Renewal
RENEWAL APPROVAL LETTER

In reply please quote: HE14/108

13 May 2015
Ms Deborah Chadwick
233 Rainbow St
Coogee NSW 2034

Dear Ms Chadwick,

Thank you for submitting the progress report. I am pleased to advise that renewal of the following Human Research Ethics application has been approved.

Ethics Number: HE14/108
Project Title: Providing Working Memory (WM) Support for Anxious Students using Cognitive Load Theory Compliant Instructions
Researchers: Ms Deborah Chadwick, Dr Shirley Agostinho, Dr Sharon Tindall-Ford
Renewed From: 29 May 2015
New Expiry Date: 28 May 2016

Please note that approvals are granted for a twelve month period. Further extension will be considered on receipt of a progress report prior to expiry date.

This certificate relates to the research protocol submitted in your original application and all approved amendments to date. Please remember that in addition to completing an annual report, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforeseen events that might affect continued ethical acceptability of the project.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/UOW009385.html This report must be completed, signed by the appropriate Head of School and returned to the Research Services Office prior to the expiry date.

Yours sincerely

Associate Professor Melanie Randle
Chair, UOW Social Sciences
Human Research Ethics Committee
The University of Wollongong/ Illawarra and Shoalhaven Local Health Network District (ISLHD) Social Science HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.

Ethics Unit, Research Services Office University of Wollongong NSW 2522 Australia Telephone (02) 4221 3386 Facsimile (02) 4221 4338 Email: rso-ethics@uow.edu.au Web: www.uow.edu.au

299
APPENDIX B

Instructional Materials for
CLT Compliant Condition
(Experiment 1)
INSTRUCTIONS TO PARTICIPANTS

Please complete the following booklet in the order it is presented. You will need a pen and are allowed a calculator if required. You will need a phone or watch to time yourself in each section.

Please solve each maths problem to the best of your ability and show all working out. Please record your start and finish time for each section as soon as you finish as indicated on the paper. If you change your mind about an answer to a question using a scale, cross it out and circle another one. Once you have completed a section and filled in the time, do not go back and make any more changes. Be aware that the scales do change in different sections of the booklet.

For the 16 questions following each section of maths problem, please refer to the following scales.

Q1 → 6:
1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7 → 16
0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case
Please answer the questions as honestly as possible.
All responses will remain confidential. You will not be identified. Only the researcher will see the completed worksheets and look at results. The data collected from the results of the worksheets will be used solely for the purpose of the research.

The research does not form part of your assessment in any way. Hopefully you may find doing this task helpful in some way.

The research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.

Thank you for your participation in this experiment and contributing to my research.

Before you start, please complete the following details:

First Name: ________________________________________________________________

Age: __________________________ Gender: Male / Female

Maths Class: _____________________________________________________________

PART 1 – ABBREVIATED MATHS ANXIETY SCALE (AMAS)

This section contains a number of statements about mathematics. You will be asked what you think about these statements. There are no “right” or “wrong” answers. Your opinion is important.

Please rate each item in terms of how anxious you would feel during the event specified. Use the following scale and record your answer by drawing a circle around the number that best describes your opinion.
1 = Low Anxiety
2 = Some Anxiety
3 = Moderate Anxiety
4 = Quite a bit of Anxiety
5 = High Anxiety

1. Having to use tables in the back of a math book.

2. Thinking about an upcoming math test one day before.

3. Watching a teacher work an algebraic equation on the board.

4. Taking an examination in a math course.
5. Being given a homework assignment of many difficult problems that is due in the next class meeting.

6. Listening to a lecture in math class.

7. Listening to another student explain a math formula.

8. Being given a “pop” quiz in a math class.

PART 2 - MATHS PROBLEMS

SECTION A

For each question, study the worked example and then answer the question in the solution space provided showing all your working out. The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

Record Start Time: ______________________________

EXAMPLE

1. Solve for \( x \) \( x + 2 = 19 \)

\[
\begin{align*}
\ x + 2 - 2 & = 19 - 2 \\
\ x & = 17 
\end{align*}
\]

(subtract 2 from each side)

QUESTION

Solve for \( y \) \( y - 4 = 12 \)

SOLUTION

EXAMPLE

2. Solve for \( x \) \( 3x + 5 = 20 \)

\[
\begin{align*}
\ 3x + 5 - 5 & = 20 - 5 \\
\ 3x & = 15 \\
\ 3x + 3 - 15 + 3 & = 15 + 3 \\
\ x & = 5 
\end{align*}
\]

(subtract 5 from both sides)

(divide both sides by 3)

QUESTION

Solve for \( y \) \( 2y + 1 = 25 \)

SOLUTION

305
EXAMPLE

3. Solve for $a$  \[2a + 7 = -9\]

\[
2a + 7 \quad \underline{\text{subtract 7 from both sides}} \quad = -9 - 7
\]

\[2a = -16\]

\[
2a \div 2 = -16 \div 2
\]

\[a = -8\]

QUESTION

Solve for $b$  \[4b - 5 = 11\]

SOLUTION


EXAMPLE

4. Solve for $x$  \[3x - 5 = 13\]

\[
3x - 5 \quad \underline{\text{add 5 to both sides}} \quad = 13 + 5
\]

\[3x = 18\]

\[
3x \div 3 = 18 \div 3
\]

\[x = 6\]

QUESTION

Solve for $x$  \[5x - 6 = 14\]

SOLUTION


EXAMPLE

5. Solve for $y$ $y - 9 = -12$

\begin{align*}
y - 9 + 9 &= -12 + 9 \\
y &= -3
\end{align*}

(add 9 to both sides)

QUESTION

Solve for $x$ $x - 5 = -8$

\begin{align*}
x - 5 + 5 &= -8 + 5 \\
x &= -3
\end{align*}

SOLUTION

\begin{align*}
\text{Record Finish Time: } &
\end{align*}
Please answer the following questions with regard to the maths problems just completed in Section A. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).
Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task.

1  2  3  4  5  6  7  8  9

Extremely Low

2. Rate the level of satisfaction with your performance on the task.

1  2  3  4  5  6  7  8  9

Extremely Low

3. Rate the level of importance you place on this task.

1  2  3  4  5  6  7  8  9

Extremely Low
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.
8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
SECTION B

For each question, study the worked example and then answer the question in the solution space provided showing all your working out. The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

EXAMPLE

1. Solve for $x$  

$$\frac{x + 3}{7} = 3$$

$$7 \times \frac{x + 3}{7} = 3 \times 7$$  \hspace{1cm} \text{(multiply both sides by 7)}

$$x + 3 = 21$$

$$x + 3 - 3 = 21 - 3$$  \hspace{1cm} \text{(subtract 3 from both sides)}

$$x = 18$$

QUESTION

Solve for $x$  

$$\frac{x - 1}{3} = 4$$

SOLUTION

_________________________

_________________________

_________________________

_________________________
EXAMPLE

2. Solve for $y$ \[6y + 7 = 4y + 13\]

\[
\begin{align*}
6y - 4y + 7 &= 4y - 4y + 13 \\
2y + 7 &= 13 \\
2y + 7 - 7 &= 13 - 7 \\
2y &= 6 \\
2y \div 2 &= 6 \div 2 \\
y &= 3
\end{align*}
\]

(subtract 4y from both sides)

(subtract 7 from both sides)

(divide both sides by 2)

QUESTION

Solve for $m$ \[2m + 4 = m + 9\]

\[\text{SOLUTION}\]


EXAMPLE

3. Solve for $x$ \[2x^2 = 32\]

\[
\begin{align*}
2x^2 \div 2 &= 32 \div 2 \\
x^2 &= 16 \\
\sqrt{x^2} &= \sqrt{16} \\
x &= \pm 4
\end{align*}
\]

(divide both sides by 2)

(find square root of both sides)

(note positive and negative answer)

QUESTION

Solve for $x$ \[5x^2 = 125\]

\[\text{SOLUTION}\]


313
EXAMPLE

4. Solve for $a$  \[4(a + 1) = a + 10\]

\[
4a + 4 = a + 10 \\
4a - a + 4 = a - a + 10 \quad \text{(subtract $a$ from both sides)} \\
3a + 4 = 10 \\
3a + 4 - 4 = 10 - 4 \quad \text{(subtract 4 from both sides)} \\
3a = 6 \\
3a \div 3 = 6 \div 3 \quad \text{(divide both sides by 3)} \\
a = 2
\]

QUESTION

Solve for $x$  \[3(x + 2) = x + 4\]

\[\text{SOLUTION}\]
EXAMPLE

5. Solve for $y$ \hspace{1cm} y^2 + 5 = 30

\begin{align*}
  y^2 + 5 & = 30 - 5 \\
  y^2 & = 25 \\
  \sqrt{y^2} & = \sqrt{25} \\
  y & = \pm 5
\end{align*}

(subtract 5 from both sides)

(find square root of both sides)

(note positive and negative answer)

QUESTION

Solve for $x$ \hspace{1cm} x^2 - 4 = 32

SOLUTION

Record Finish Time: ____________________________
Please answer the following questions with regard to the maths problems just completed in Section B. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning *not at all the case*) to 10 (meaning *completely the case*).

1. Rate the mental effort required to complete the task.

   1  2  3  4  5  6  7  8  9

   Extremely Low

2. Rate the level of satisfaction with your performance on the task.

   1  2  3  4  5  6  7  8  9

   Extremely Low

3. Rate the level of importance you place on this task.

   1  2  3  4  5  6  7  8  9

   Extremely Low
4. Rate the difficulty of the task.

1  2  3  4  5  6  7  8  9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0  1  2  3  4  5  6  7  8  9  10
8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

9. The task covered concepts that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

10. The instructions and/or explanations during the task were very unclear.

0 1 2 3 4 5 6 7 8 9 10

11. The instructions and/or explanations were, in terms of learning, very ineffective.

0 1 2 3 4 5 6 7 8 9 10

12. The instructions and/or explanations were full of unclear language.

0 1 2 3 4 5 6 7 8 9 10
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
SECTION C
For each question, study the worked example and then answer the question in the solution space provided showing all your working out. The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

Record Start Time: _________________________________

EXAMPLE
1. Solve for \( b \) \( \frac{2b}{3} + \frac{3b}{5} = \frac{2}{3} \)

\[
\begin{align*}
10b + 9b &= 2 \\
15 &
\end{align*}
\]

\[
\begin{align*}
19b &= 2 \\
15 &
\end{align*}
\]

\[
\begin{align*}
15 \times 19b &= 2 \times 15 \\
15 &
\end{align*}
\]

\[
\begin{align*}
19b &= 30 \\
19 &
\end{align*}
\]

\[
\begin{align*}
b &= 30 \\
19 &
\end{align*}
\]

QUESTION
Solve for \( a \) \( \frac{a}{4} + \frac{2a}{3} = \frac{5}{3} \)

SOLUTION

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________
EXAMPLE

2. Solve for $b$ \((b - 3)^2 = 16\)
   \[
   \sqrt{(b - 3)^2} = \sqrt{16}
   \]
   \[
   b - 3 = \pm 4
   \]
   \[
   b - 3 + 3 = \pm 4 + 3
   \]
   \[
   b = -1, 7
   \]

QUESTION
Solve for $y$ \((y - 2)^2 = 16\)

EXAMPLE

3. Solve for $y$ \(2y^2 + 14y + 20 = 0\)
   \[
   2(y^2 + 7y + 10) = 0
   \]
   \[
   \frac{2(y^2 + 7y + 10)}{2} = 0
   \]
   \[
   y^2 + 7y + 10 = 0
   \]
   \[
   (y + 5)(y + 2) = 0
   \]
   \[
   y + 5 = 0; y + 2 = 0
   \]
   \[
   y = -5, -2
   \]

QUESTION
Solve for $x$ \(2x^2 + 10x + 12 = 0\)

SOLUTION

SOLUTION

SOLUTION
EXAMPLE

4. Solve for \( a \) \( 2a^2 + 10a = -8 \)

\[
2a^2 + 10a + 8 = -8 + 8 \quad (\text{Make equation equal zero})
\]

\[
2(a^2 + 5a + 4) = 0 \quad (\text{take out common factor})
\]

\[
2(a^2 + 5a + 4) = 0 \quad (\text{divide both sides by common factor } 2)
\]

\[
a^2 + 5a + 4 = 0 \quad (\text{factorise - factors multiply to give } 4 \text{ and add to give } 5)
\]

\[
(a + 4)(a + 1) = 0 \quad (\text{find } a)
\]

\[
a + 4 = 0; \ a + 1 = 0
\]

\[
a = -4, -1
\]

QUESTION

Solve for \( x \) \( 3x^2 + 12x = 15 \)

SOLUTION
EXAMPLE

5. Solve for $h$  \hspace{0.5cm} h (3h - 6) = 24

\[
3h^2 - 6h = 24
\]
\[
3h^2 - 6h - 24 = 24 - 24 \hspace{0.5cm} \text{(Make equation equal zero)}
\]
\[
3(h^2 - 2h - 8) = 0 \hspace{0.5cm} \text{(take out common factor)}
\]
\[
3(h^2 - 2h - 8) = 0 \hspace{0.5cm} \text{(divide both sides by common factor 3)}
\]
\[
\frac{h^2 - 2h - 8}{3} = \frac{0}{3}
\]
\[
h^2 - 2h - 8 = 0 \hspace{0.5cm} \text{(factorise - factors multiply to give -8 and add to give -2)}
\]
\[
(h + 2)(h - 4) = 0
\]
\[
h + 2 = 0; \hspace{0.5cm} h - 4 = 0 \hspace{0.5cm} \text{(find h)}
\]
\[
h = -2, \hspace{0.5cm} 4
\]

QUESTION

Solve for $x$  \hspace{0.5cm} x (2x - 6) = 20

SOLUTION

Record Finish Time: ______________________
Please answer the following questions with regard to the maths problems just completed in Section C. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task.

1 2 3 4 5 6 7 8 9

Extremely Low

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

Extremely Low

3. Rate the level of importance you place on this task.

1 2 3 4 5 6 7 8 9

Extremely Low
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.
8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.

END OF PAPER 1 – THANK YOU
APPENDIX C

Instructional Materials for
CLT Non-Compliant Condition
(Experiment 1)
INSTRUCTIONS TO PARTICIPANTS

Please complete the following booklet in the order it is presented.
You will need a pen and are allowed a calculator if required.
You will need a phone or watch to time yourself in each section.

Please solve each maths problem to the best of your ability and show all working out.

Please record your start and finish time for each section as soon as you finish as indicated on the paper.
If you change your mind about an answer to a question using a scale, cross it out and circle another one.
Once you have completed a section and filled in the time, do not go back and make any more changes.
Be aware that the scales do change in different sections of the booklet.

For the 16 questions following each section of maths problem, please refer to the following scales.

Q1→6:
1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7 → 16
0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case

Please answer the questions as honestly as possible.
All responses will remain confidential. You will not be identified. Only the researcher will see the completed worksheets and look at results. The data collected from the results of the worksheets will be used solely for the purpose of the research.

The research does not form part of your assessment in any way. Hopefully you may find doing this task helpful in some way.

The research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.
Thank you for your participation in this experiment and contributing to my research.

**Before you start, please complete the following details:**

First Name: ____________________________________________________________

Age: ____________________ Gender: Male / Female

Maths Class: ____________________________________________________________

**PART 1 – ABBREVIATED MATHS ANXIETY SCALE (AMAS)**

This section contains a number of statements about mathematics. You will be asked what you think about these statements. There are no “right” or “wrong” answers. Your opinion is important.
Please rate each item in terms of how anxious you would feel during the event specified. Use the following scale and record your answer by drawing a circle around the number that best describes your opinion.
1. Having to use tables in the back of a math book.

2. Thinking about an upcoming math test 1 day before.

3. Watching a teacher work an algebraic equation on the board.

4. Taking an examination in a math course.
5. Being given a homework assignment of many difficult problems that is due in the next class meeting.

6. Listening to a lecture in math class.

7. Listening to another student explain a math formula.

8. Being given a “pop” quiz in math class.

PART 2 MATHS PROBLEMS

SECTION A

For each of the following, answer the question in the solution space provided showing all your working out.

Record Start Time: ________________________________

SOLUTION

1. Solve for \( y \) \( y - 4 = 12 \) ______________________________________________________
   ______________________________________________________
   ______________________________________________________

2. Solve for \( y \) \( 2y + 1 = 25 \) ______________________________________________________
   ______________________________________________________
   ______________________________________________________

3. Solve for \( b \) \( 4b - 5 = 11 \) ______________________________________________________
   ______________________________________________________
   ______________________________________________________

4. Solve for \( x \) \( 5x - 6 = 14 \) ______________________________________________________
   ______________________________________________________
   ______________________________________________________
5. Solve for \( x \)  
\[ x - 5 = -8 \]

Record Finish Time: _________________________

Please answer the following questions with regard to the maths problems just completed in Section A. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning *not at all the case*) to 10 (meaning *completely the case*).

1. Rate the mental effort required to complete the task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely Low</th>
<th>Extremely High</th>
</tr>
</thead>
</table>

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely Low</th>
<th>Extremely High</th>
</tr>
</thead>
</table>
3. Rate the level of importance you place on this task.

Extremely Low

4. Rate the difficulty of the task.

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

Extremely Low
Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.
12. The instructions and/or explanations were full of unclear language.

13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
SECTION B

For each of the following, answer the question in the solution space provided showing all your working out.

Record Start Time: _________________________________

SOLUTION

1. Solve for \(x\)
   \[
   \frac{x - 1}{3} = 4
   \]

2. Solve for \(m\)
   \[
   2m + 4 = m + 9
   \]

3. Solve for \(x\)
   \[
   5x^2 = 125
   \]
4. Solve for \( x \) \( 3(x + 2) = x + 4 \)

5. Solve for \( x \) \( x^2 - 4 = 32 \)

Record Finish Time: ________________________________

Please answer the following questions with regard to the maths problems just completed in Section B. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).
Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task.

1  2  3  4  5  6  7  8  9

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Extremely Low | Extremely High |
2. Rate the level of satisfaction with your performance on the task.

1  2  3  4  5  6  7  8  9

Extremely Low

3. Rate the level of importance you place on this task.

1  2  3  4  5  6  7  8  9

Extremely Low

4. Rate the difficulty of the task.

1  2  3  4  5  6  7  8  9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low
6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10

8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

9. The task covered concepts that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

10. The instructions and/or explanations during the task were very unclear.

0 1 2 3 4 5 6 7 8 9 10
11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.

13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
SECTION C

For each of the following, answer the question in the solution space provided showing all your working out.

Record Start Time: ________________________________

SOLUTION

1. Solve for $a \quad \frac{a}{4} + \frac{2a}{3} = 5$

2. Solve for $y \quad (y - 2)^2 = 16$
3. Solve for \( x \)
\[ 2x^2 + 10x + 12 = 0 \]

4. Solve for \( x \)
\[ 3x^2 + 12 = 15 \]
5. Solve for \( x \) \( x(2x - 6) = 20 \)

Record Finish Time: ___________________
Please answer the following questions with regard to the maths problems just completed in Section C. These questions relate to two separate established rating scales. Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task.

1 2 3 4 5 6 7 8 9

Extremely Low

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

Extremely Low

3. Rate the level of importance you place on this task.

1 2 3 4 5 6 7 8 9

Extremely Low
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low
High

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low
High

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low
High

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.
8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

9. The task covered concepts that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

10. The instructions and/or explanations during the task were very unclear.

0 1 2 3 4 5 6 7 8 9 10

11. The instructions and/or explanations were, in terms of learning, very ineffective.

0 1 2 3 4 5 6 7 8 9 10

12. The instructions and/or explanations were full of unclear language.

0 1 2 3 4 5 6 7 8 9 10
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.

END OF PAPER 1 – THANK YOU
APPENDIX D

Product-oriented worked example sheet for
CLT Non-Compliant Condition
(Experiment 1)
These worked examples are provided for you to refer to when answering the questions in the mathematics worksheet.

1. \[ x + 2 = 19 \]
   \[ x + 2 - 2 = 19 - 2 \]
   \[ x = 17 \]

2. \[ 2a + 7 = -9 \]
   \[ 2a + 7 - 7 = -9 - 7 \]
   \[ 2a = -16 \]
   \[ 2a ÷ 2 = -16 ÷ 2 \]
   \[ a = -8 \]

3. \[ \frac{x + 3}{7} = 3 \]
   \[ 7 \times (x + 3) = 3 \times 7 \]
   \[ x + 3 = 21 \]
   \[ x + 3 - 3 = 21 - 3 \]
   \[ x = 18 \]

4. \[ 4(a + 1) = a + 3 \]
   \[ 4a + 4 = a + 10 \]
   \[ 4a - a + 4 = a - a + 10 \]
   \[ 3a + 4 = 10 \]
   \[ 3a + 4 - 4 = 10 - 4 \]
   \[ 3a = 6 \]
   \[ 3a ÷ 3 = 6 ÷ 3 \]
   \[ a = 2 \]

5. \[ h (3h - 6) = 24 \]
   \[ 3h^2 - 6h = 24 \]

6. \[ 2y^2 + 14y + 20 = 0 \]
   \[ 2(y^2 + 7y + 10) = 0 \]
   \[ 2(y^2 + 7y + 10) = 0 \]
   \[ 2 \]
   \[ y^2 + 7y + 10 = 0 \]
   \[ (y + 5)(y + 2) = 0 \]
   \[ y + 5 = 0; y + 2 = 0 \]
   \[ y = -5, -2 \]

7. \[ \frac{2b}{3} \] \[ + \] \[ \frac{3b}{5} = 2 \]
   \[ \frac{10b + 9b}{15} = 2 \]
   \[ \frac{19b}{15} = 2 \]
   \[ 15 \]
   \[ 15 \times 19b = 2 \times 15 \]
   \[ 15 \]
   \[ 19b = 30 \]
   \[ 19b / 19 = 30 / 19 \]
   \[ b = 30 / 19 \]
APPENDIX E

Permission to use instruments correspondence
Dear Dr Hopko,

I am currently completing my PhD at the University of Wollongong, NSW, Australia. My research is investigating the impact of maths instruction compliant with cognitive load theory on the level of maths anxiety experienced during testing. My review of literature has identified the Abbreviated Maths Anxiety Scale as the most appropriate tool to be used in my experiments. I would like to ask your permission to use this instrument in my research which will obviously be appropriately acknowledged in my thesis.

Kind regards,
Deborah Chadwick
Dear Prof Paas,

As you are aware, I am currently completing my PhD at the University of Wollongong, NSW, Australia. My research is investigating the impact of maths instruction compliant with cognitive load theory on the level of maths anxiety experienced during testing. My review of literature has identified your cognitive load subjective rating scale to incorporate into my testing materials to be used in my experiments. I hope to use this in conjunction with the recently developed scale to differentiate between types of cognitive load developed by Dr Leppink. This will be useful as I hope to calculate measures of efficiency as well as identify cognitive load associated with various levels of element interactivity which can be further supported by data related to the type of load associated with a task. I would like to ask your permission to use this instrument in my research which will obviously be appropriately acknowledged in my thesis.

Kind regards,
Deborah Chadwick

RE: Permission to use Cognitive Load Subjective Rating Scale

Fred Paas <fredp@uow.edu.au>
Tue 29/07/2014 10:40 PM

To: Deborah Chadwick;

Hi Deborah,

Sure, you can use the scale if you appropriately acknowledge my research.
Don't hesitate to ask me when you have questions.
Good luck with your research.

Best wishes,
Fred
Dear Dr Baloglu,

I am currently completing my PhD at the University of Wollongong, NSW, Australia. My research is investigating the impact of maths instruction compliant with cognitive load theory on the level of maths anxiety experienced during testing. My review of literature has identified your scale for subjects to subjectively measure their level of anxiety as a worthwhile instrument to incorporate into my testing materials to be used in my experiments. This will be useful as I hope to identify anxiety levels both between participants under various conditions and also using a within subjects design for anxiety levels associated with particular tasks. I would like to ask your permission to use this instrument in my research which will obviously be appropriately acknowledged in my thesis.

Kind regards,
Deborah Chadwick

---

Re: Permission to use subjective measure of anxiety scale

Mustafa Baloglu, Ph.D. <baloglu@hotmail.com>
Tue 29/07/2014 8:12 PM

To: Deborah Chadwick;

You have my permission to use it for your research
Sincerely yours,

Prof. Dr. Mustafa Baloglu
Hacettepe University
School of Education
Dear Dr Leppink,

I am currently completing my PhD at the University of Wollongong, NSW, Australia. My research is investigating the impact of maths instruction compliant with cognitive load theory on the level of maths anxiety experienced during testing. My review of literature has identified your recently developed scale to differentiate between types of cognitive load as a worthwhile instrument to incorporate into my testing materials to be used in my experiments. This will be useful as I hope to identify cognitive load associated with various levels of element interactivity which can be further supported by data related to the type of load associated with a task. I would like to ask your permission to use this instrument in my research which will obviously be appropriately acknowledged in my thesis.

Kind regards,

Deborah Chadwick
APPENDIX F

Consent Form
(Experiment 1)
Consent form for Secondary Students and Parents

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

I have been given information about “Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions”. I have had the opportunity to ask any further questions I have regarding the research. This is part of a PhD degree supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford from the School of Education, Faculty of Social Science, at the University of Wollongong. I understand that my/my child’s participation in this research is voluntary and I may withdraw at any time from the study without affecting my/my child’s treatment at school in any way.

I understand that if I consent, participation in this project will involve one session of approximately 90 minutes at school during which time a series of maths tasks and related questions will be answered on worksheets provided. I understand that my/my child’s contribution will be confidential and my/my child’s name will not be used to identify my comments or work in the study. I understand that there are no potential risks or burdens associated with this study.

I understand that participation in this research is voluntary and I am free to refuse to participate and I am free to withdraw consent to participate in the research at any time. Refusal to participate or withdrawal of consent will not affect my/my child’s relationship with the Faculty of Education at the University of Wollongong.

If I have any concerns regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, University of Wollongong on 4221 3386 or email rso-ethics@uow.edu.au.

I understand that the data collected from my/my child’s participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication and conference presentations, and I consent for it to be used in that manner.

Many thanks for your consideration of participating in this research.
Please return the completed consent below and return to your class maths teacher by Thursday 19\textsuperscript{th} June 2014.

\section*{PARENT AND STUDENT CONSENT}

By signing below I am indicating my consent to my/my child’s participation in the research. I understand that the data collected from my/my child’s participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication, and I consent for it to be used in that manner.

I give permission for my child………………………………… to participate in this research.

Parent/ Guardian Signature …………………………………… Date …………………

Name (please print) ……………………………………………………………………………

Child’s signature ……………………………………………………………………………

\section*{REVOCATION OF CONSENT}

I hereby wish to WITHDRAW my consent for my/my child’s participation in the research described above and understand that such withdrawal WILL NOT jeopardise any treatment by, or my/my child’s relationship with, The University of Wollongong.

…………………………… ……………………………… ………………………………

Signature of Student Please PRINT name Date

…………………………… ……………………………… ………………………………

Signature of Parent Please PRINT name Date
APPENDIX G

Participant Information Sheet

(Experiment 1)

for

1. parent / guardian

2. student
Dear Parent / Guardian,

Your child has been invited to participate in a study of **Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions**. The purpose of the research is to investigate the impact of providing worked examples in mathematics instruction on the performance of students of all abilities with materials of varying difficulty and how this interacts with student anxiety related to mathematics. Your child has been selected as a possible participant in this study because the instructional materials designed for the investigation are appropriate for students working towards Stage 5 outcomes.

INVESTIGATORS

Deborah Chadwick
PhD candidate
dmc490@uowmail.edu.au

Shirley Agostinho
School of Education
Faculty of Social Science
shirleyA@uow.edu.au

Deborah Chadwick
PhD candidate
dmc490@uowmail.edu.au

Shirley Agostinho
School of Education
Faculty of Social Science
shirleyA@uow.edu.au

WHAT WE WOULD LIKE TO DO

If you decide to allow your child to participate, they will be asked to complete a series of questionnaires and algebra worksheets based on the Year 9/10 NSW mathematics syllabus. The worksheet will require the transfer of their understanding of material and a measure of the number of correct responses will be made. In addition, students will be asked to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. Typical questions include: \( 2x - 3 = 7 \) and \( 3y + 8 = 2y - 5 \) for the maths task; Indicate the level of anxiety you experience listening to a lecture in a maths class and Rate the difficulty of this task for the questionnaire. The entire testing will require approximately 90 minutes and will take place at the College. We can foresee no risks for your child as a result of participating in this study.

Any information that is obtained in connection with this study and that can be identified with your child will remain confidential and will be disclosed only with your permission, except as required by law. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers. In any publication, information will be presented in such a way that your child, their school and their teacher will not be able to be identified.

The data collected from the results of the worksheets will be used solely for the purpose of the research identified in this letter. Research findings will be available to research participants at the completion of the study through the University of Wollongong.

361
ETHICS AND COMPLAINTS

This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. Any concerns or complaints regarding this research may be directed to the UoW Ethics Officer (phone 4221 3386, email rso-ethics@uow.edu.au).

Your decision whether to not to allow your child to participate will not prejudice you or your child’s future relations with the University of Wollongong. If you decide to allow your child to participate, you are free to withdraw your consent and to discontinue your child’s participation at any time without prejudice.

Thank you for your interest in this study.

Deborah Chadwick
PARTICIPANT INFORMATION SHEET FOR STUDENT

Researcher: Deborah Chadwick

Dear Student,

You are invited to participate in a study of Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions. The purpose of the research is to investigate the impact of providing worked examples in mathematics instruction on the performance of students of all abilities with materials of varying difficulty and how this interacts with student anxiety related to mathematics. You have been selected as a possible participant in this study because the instructional materials designed for the investigation are appropriate for students working towards Stage 5 outcomes.

INVESTIGATORS
Deborah Chadwick  PhD candidate
dmc490@uowmail.edu.au

PRINCIPAL SUPERVISOR
Shirley Agostinho  Shirley Agostinho
School of Education  School of Education
shirleyA@uow.edu.au  shirleyA@uow.edu.au

CO-SUPERVISOR
Sharon Tindall_ford  Sharon Tindall_ford
Faculty of Social Science  Faculty of Social Science
sharontf@uow.edu.au

WHAT WE WOULD LIKE YOU TO DO
If you decide to participate, you will be asked to complete a series of questionnaires and algebra worksheets based on the Year 9/10 NSW mathematics syllabus. The worksheet will require the transfer of your understanding of material and a measure of the number of correct responses will be made. In addition, you will be asked to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. Typical questions include: $2x - 3 = 7$ and $3y + 8 = 2y - 5$ for the maths task; Indicate the level of anxiety you experience listening to a lecture in a maths class and Rate the difficulty of this task for the questionnaire. The entire testing will require approximately 90 minutes and will take place at the College. We can foresee no risks for you as a result of participating in this study.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission, except as required by law. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers. In any publication, information will be presented in such a way that you, your school and your teacher will not be able to be identified.
The data collected from the results of the worksheets will be used solely for the purpose of the research identified in this letter. Research findings will be available to research participants at the completion of the study through the University of Wollongong.

ETHICS REVIEW AND COMPLAINTS
This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. Any concerns or complaints regarding this research may be directed to the UoW Ethics Officer (phone 4221 3386, email rso-ethics@uow.edu.au).

Your decision whether to not to participate will not prejudice your future relations with the University of Wollongong. If you decide to participate, you are free to withdraw your consent and to discontinue your participation at any time without prejudice.

Thank you for your interest in this study.

Deborah Chadwick
APPENDIX H

Teacher Information Sheet
(Experiment 1)
Thank you very much for your interest in the above research conducted by the School of Education, Faculty of Social Science, University of Wollongong. The research is being conducted as part of my PhD supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford.

The purpose of this study is to examine the interrelationship between working memory, cognitive load and anxiety. The research will specifically focus on instructional materials in the domain of mathematics and examine whether mathematics performance is improved for highly anxious learners as a result of the reduced working memory load associated with cognitive load theory compliant instructional material, as well as examine if there is a reduction in student anxiety levels.

The research will involve Year 10 mathematics students. They will be required to complete a series of algebra worksheets based on the Year 9/10 NSW mathematics syllabus and a measure of the number of correct responses will be made. In addition, students will be required to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. The entire testing will require approximately 90 minutes and will take place at the College. We can foresee no risks for your child as a result of participating in this study.

Participants will be provided with all materials required for the research. Teachers, students and parents will be provided with information sheets explaining the research and outlining the tasks involved in advance of their participation in the research. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers.

If there are any ethical concerns you can contact the Ethics Officer, Human Research Ethics Committee, University of Wollongong on (02) 4221 3386 or email rso-ethics@uow.edu.au. Should you require any further information please do not hesitate to contact members of the research team.

Yours sincerely

Deborah Chadwick
APPENDIX I

Instructions for Teachers
(Experiment 1)
INSTRUCTIONS TO TEACHERS

• There are two different work booklets – only some have a page insert – this is intended (papers with “CN” in footer have insert)
• Students are to complete assigned worksheets – distributed randomly (2 groups).
• Please read through the front page of the booklets with the students.

• No further directions permitted once testing has begun.

Please reassure them of their anonymity and the fact that the completed data is seen / used by the researcher only.

INSTRUCTIONS TO STUDENTS

• On front cover please put first name and surname initial only.
• Worksheets are to be completed in order.
• Students may use calculators if necessary to eliminate calculation errors which are not part of the research data required.
• Time taken must be recorded at the beginning and end of each section – you may use the stopwatch on your phone or your watch to write actual times.
• Make sure time is recorded just before you start and as soon as you are finished.
• Once you have completed a section and filled in the time, do not go back and make any changes.
• Students may proceed at their own pace but need to record their time.
• All answers to be completed in the booklet.
• Please answer the maths questions to the best of your ability. Show all working.
• All content on worksheets has previously been covered in class.
• Please answer the questionnaires honestly – there are no right or wrong answers for these.
• 16 questions follow each section of maths problems. Details of these scales are written on the board.

Many thanks for your assistance and participation in this research.
APPENDIX J

Additional Descriptive Statistics and Additional Findings

(Experiment 1)
Table J1

Subjective Ratings of Satisfaction, Importance, Task Difficulty and Engagement

<table>
<thead>
<tr>
<th>Variable</th>
<th>CCLA (n = 14)</th>
<th>CCHA (n = 12)</th>
<th>CNLA (n = 15)</th>
<th>CNHA (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Low EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>7.21</td>
<td>1.97</td>
<td>6.42</td>
<td>1.62</td>
</tr>
<tr>
<td>Importance</td>
<td>3.00</td>
<td>1.96</td>
<td>3.83</td>
<td>1.34</td>
</tr>
<tr>
<td>Difficulty</td>
<td>1.57</td>
<td>0.76</td>
<td>2.25</td>
<td>0.87</td>
</tr>
<tr>
<td>Engagement</td>
<td>3.79</td>
<td>1.89</td>
<td>4.92</td>
<td>2.57</td>
</tr>
<tr>
<td>Moderate EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6.50</td>
<td>1.83</td>
<td>5.08</td>
<td>2.23</td>
</tr>
<tr>
<td>Importance</td>
<td>3.50</td>
<td>1.87</td>
<td>3.92</td>
<td>1.62</td>
</tr>
<tr>
<td>Difficulty</td>
<td>3.29</td>
<td>1.59</td>
<td>4.67</td>
<td>1.78</td>
</tr>
<tr>
<td>Engagement</td>
<td>3.79</td>
<td>2.19</td>
<td>5.42</td>
<td>2.23</td>
</tr>
<tr>
<td>High EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6.43</td>
<td>1.60</td>
<td>4.08</td>
<td>2.50</td>
</tr>
<tr>
<td>Importance</td>
<td>4.79</td>
<td>2.22</td>
<td>3.75</td>
<td>1.36</td>
</tr>
<tr>
<td>Difficulty</td>
<td>4.68</td>
<td>1.54</td>
<td>6.25</td>
<td>1.91</td>
</tr>
<tr>
<td>Engagement</td>
<td>5.07</td>
<td>1.69</td>
<td>5.33</td>
<td>2.27</td>
</tr>
</tbody>
</table>

Table J2

Descriptive Statistics - Intrinsic Cognitive Load

<table>
<thead>
<tr>
<th>Element (EI)</th>
<th>CONDITION</th>
<th>CLT compliant n=36</th>
<th>CLT non-compliant n=35</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICL: Mean (SD)</td>
<td>ICL: Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Low (/30)</td>
<td>2.54 (3.32)</td>
<td>2.86 (5.15)</td>
<td></td>
</tr>
<tr>
<td>Moderate (/30)</td>
<td>6.84 (5.54)</td>
<td>7.94 (6.45)</td>
<td></td>
</tr>
<tr>
<td>High (/30)</td>
<td>13.06 (6.49)</td>
<td>14.44 (8.18)</td>
<td></td>
</tr>
<tr>
<td>Total (/90)</td>
<td>21.96 (12.20)</td>
<td>25.24 (15.66)</td>
<td></td>
</tr>
</tbody>
</table>
1. Part 3 Results: Additional Findings – Mental Effort

Additional analysis of mental effort was conducted in terms of low element interactivity and low anxiety variables, the relationship between mental effort and participants’ expertise, task completion time, and efficiency. Variations in mental effort ratings associated with element interactivity and participant anxiety may have also influenced task completion times. In addition, mental effort ratings ascertained from the CLSRS were also used to calculate instructional efficiency, in conjunction with performance scores. This allowed analysis of the effectiveness of the materials used at different levels of element interactivity and for participants with low and high baseline maths anxiety.

1.1 Effects for Low element interactivity and Low anxiety

Mental effort ratings for all groups were higher at higher levels of element interactivity. For highly anxious participants using CLT compliant instructional material (CCHA group), the reported mental effort ratings were significantly higher when comparing tasks of low ($t(21) = 2.199, p = .039$) and moderate ($t(22) = 2.075, p = .050$) element interactivity than highly anxious participants using CLT non-compliant instructional material (CNHA).

Of all experimental groups, the CLT compliant low anxiety group (CCLA) reported the lowest total mental effort rating (Mean = 10.79) and the CLT compliant high anxiety group (CCHA) reported the highest total mental effort rating (Mean = 14.92). In the CLT non-compliant condition, the high anxiety group (CNHA) reported higher mental effort ratings.
than the low anxiety group (CNLA) In addition, at high levels of element interactivity there was a corresponding higher rating of mental effort. Similarly, at high element interactivity, of all experimental groups, the CLT compliant low anxiety group (CCLA) reported the lowest effort overall at high element interactivity (Mean = 5.12). Conversely, the CLT non-compliant high anxiety group (CNHA) reported the highest mental effort overall (Mean = 6.59).

1.2 Self-reported Mental Effort and Efficiency

Efficiency scores are represented as a relationship between performance and mental effort, calculated using z scores. A positive efficiency score is the result of a high performance score and low mental effort rating, and is indicative of efficient learning. A negative efficiency score is the result of a low performance score and high mental effort rating, and is indicative of inefficient learning. The table below shows the efficiency scores for each condition, CLT compliant and CLT non-compliant, as well as for each group, incorporating instructional conditions and participant baseline maths anxiety.

Table J4

*Mean Efficiency Scores for Calculated using z Scores for Performance and Mental Effort Ratings*

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>Low (Part A)</th>
<th>Mod (Part B)</th>
<th>High (Part C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>-0.016</td>
<td>-0.048</td>
<td>-0.104</td>
</tr>
<tr>
<td>CN</td>
<td>-0.028</td>
<td>-0.099</td>
<td>-0.052</td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCLA</td>
<td>-0.025</td>
<td>0.035</td>
<td>-0.079</td>
</tr>
<tr>
<td>CCHA</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>CNLA</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>CNHA</td>
<td>-0.137</td>
<td>-0.087</td>
<td>-0.067</td>
</tr>
</tbody>
</table>

Results showed CLT compliant conditions generated improved levels of efficiency for participants at low and moderate element interactivity but not at high element interactivity. Efficiency measures were analysed in a 2 (Instruction Condition) x 3 (Element interactivity Condition) ANOVA. Results indicated there was no significant effect for instruction
condition at low \(F(1,65) = 0, p = 0.989\), moderate \((F(1,68) = .032, p = .859)\) or high \((F(1,67) = .116, p = .734)\) element interactivity and no interaction effect, \(F(1,64) = 0.237, p = 0.628\). Efficiency measures were also analysed in a 4 (Instruction / Anxiety Group) X 3 (Element interactivity Condition) ANOVA. Results indicated no significant effect, \(F(3,47) = .032, p = .860\).

### 1.3 Mental Effort and Expertise

A participant’s mental effort rating may be affected by their level of expertise in a specific domain. Further analysis of results in terms of expertise was conducted in order to determine the impact of expertise on cognitive load experienced by participants using CLT compliant materials. Expertise of participants was determined according to rankings from cumulative assessments undertaken within the school. This determined the participant’s allocation into graded maths classes: advanced, intermediate and standard. A one-way ANOVA was used to analyse the effect of expertise on participants’ reported mental effort rating. Results indicated a significant interaction between mental effort and the levels of expertise when solving problems of high element interactivity, \(F(45,1) = 14.386, p < .001\). Descriptive statistics for mental effort ratings of experts (participants enrolled in Advanced maths) and novices (participants enrolled in Intermediate or Standard maths) for each group when completing tasks of high element interactivity are presented in the table below.

**Table J5**

Mental Effort Ratings according to Expertise at High Element Interactivity for Each Group

<table>
<thead>
<tr>
<th>GROUP</th>
<th>CCLA Mean (SD)</th>
<th>CCHA Mean (SD)</th>
<th>CNLA Mean (SD)</th>
<th>CNHA Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novice</td>
<td>6.00 (0.00)</td>
<td>6.75 (1.75)</td>
<td>7.00 (1.41)</td>
<td>7.60 (0.55)</td>
</tr>
<tr>
<td>Expert</td>
<td>5.04 (1.45)</td>
<td>5.25 (1.26)</td>
<td>4.60 (1.17)</td>
<td>5.93 (0.55)</td>
</tr>
</tbody>
</table>

The table above shows the CLT compliant high anxiety group (CCHA), participants with expertise, reported lower subjective ratings of effort \((M = 5.25, SD=1.26)\) than novices \((M = 6.75, SD = 1.75)\). The difference between mental effort ratings of novices and experts in the CCHA group was significant, \(t(11) = 2.784, p = .019\). Similarly, in the CLT non-compliant high anxiety group (CNHA), participants with expertise reported lower subjective ratings of
effort ($M = 5.93, SD = 1.43$) than did novices ($M = 7.60, SD = 0.55$). The difference between mental effort ratings of novices and experts in the CNHA group was significant, $t(10) = 2.465, p = .033$.

### 1.4 Mental Effort and Task Completion Time

Mental Effort ratings were higher for all groups at higher levels of element interactivity. At higher levels of element interactivity, similarly greater completion times for each section were evident. The table below shows the time taken by participants to complete each of the tasks at each level of element interactivity.

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>GROUP</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA $n = 14$</td>
<td>CCHA $n = 12$</td>
<td>CNLA $n = 15$</td>
<td>CNHA $n = 12$</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>103.97 (40.53)</td>
<td>154.58 (96.23)</td>
<td>81.04 (43.56)</td>
<td>96.25 (35.37)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>169.44 (76.53)</td>
<td>265.17 (127.15)</td>
<td>120.53 (63.53)</td>
<td>183.33 (82.83)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>373.02 (161.80)</td>
<td>452.67 (174.20)</td>
<td>360.49 (271.17)</td>
<td>412.17 (130.16)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>646.43 (232.76)</td>
<td>872.42 (307.09)</td>
<td>562.06 (345.51)</td>
<td>691.75 (298.58)</td>
<td></td>
</tr>
</tbody>
</table>

Participants using CLT compliant instructions reported higher completion times for problems at all levels of element interactivity. Overall, the CLT compliant condition recorded a greater total time taken to complete the maths tasks (Mean = 736 secs, SD = 286.7) compared to the CLT non-compliant condition (Mean = 642 secs, SD = 274.5). However, this effect was not significant, $F(69,1) = 1.971, p = .165$. The table above shows for all groups, at higher levels of element interactivity, the time taken to complete a task was greater. This effect was significant, $F(2,156) = 69.523, p < .001$. Results from a one-way ANOVA for task completion time indicated a significant main effect between the four experimental groups, $F(3,49) = 2.757, p = .052$. In addition, in both the CLT compliant and CLT non-compliant conditions, those participants identified as having high baseline anxiety levels (CCHA and CNHA) took more time to complete each task in comparison to those with low maths anxiety (CCLA and CNLA). Analysis using Pearson’s correlation coefficient was undertaken to investigate the relationship between participants’ mental effort.
ratings and participants’ completion time at each level of element interactivity. There was a significant correlation between mental effort and time taken to complete task at low \( (r = .407, n = 70, p < .001) \), moderate \( (r = .452, n = 71, p = < .001) \) and high \( (r = .512, n = 70, p < .001) \) element interactivity.

Overall, completion times for tasks were greater when completing tasks of higher element interactivity and corresponded to the higher cognitive load associated with more complex tasks. In both the CLT compliant condition and the CLT non-compliant condition, task completion time was greatest for high anxiety participants, with CLT compliant high anxiety group (CCHA) the highest overall.

2. Part 3 Results: Additional Findings - GCL and Task Importance

Further analysis of participants’ reported germane cognitive load was conducted in terms of its relationship with participants’ rating of task importance. This was investigated in order to determine whether a learner was more inclined to invest germane resources into a task if it was deemed to be of greater importance.

Participants reported the level of importance they placed on each task throughout the testing. A score between 1 and 9 was recorded on a likert scale for “Rate the level of importance of this task”. Descriptive statistics for the four groups are presented in the table below.

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>GROUP</th>
<th>CCLA n = 14 Mean (SD)</th>
<th>CCHA n = 12 Mean (SD)</th>
<th>CNLA n = 15 Mean (SD)</th>
<th>CNHA n = 12 Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>3.00 (1.96)</td>
<td>3.83 (1.34)</td>
<td>2.87 (1.81)</td>
<td>4.45 (2.54)</td>
</tr>
<tr>
<td>Moderate</td>
<td></td>
<td>3.50 (1.87)</td>
<td>3.92 (1.62)</td>
<td>2.73 (1.75)</td>
<td>4.92 (2.43)</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td>4.79 (2.22)</td>
<td>3.75 (1.36)</td>
<td>3.33 (2.23)</td>
<td>4.92 (1.83)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>24.29 (18.28)</td>
<td>30.50 (20.92)</td>
<td>15.47 (16.92)</td>
<td>36.50 (28.21)</td>
</tr>
</tbody>
</table>

Analysis using Pearson’s Correlation coefficient was performed to investigate whether there was a relationship between the level of importance placed on a task and the investment of
germane resources. Based on the results, there was a significant positive correlation between the reported importance of the task and the reported GCL at high element interactivity: $r = 0.295$, $n = 53$, $p = .032$. As the participants’ rating of the level of importance of the task increased, the investment of germane resources into the task increased. Likewise, the lowest GCL ratings reported by the CNLA group were accompanied by the lowest ratings of task importance, compared to all other groups at all levels of element interactivity.
APPENDIX K

Instructional Materials for
CLT Compliant Condition
(Experiment 2)
PARTICIPANT BOOKLET - Paper 1

INSTRUCTIONS TO PARTICIPANTS

The research does not form part of your assessment in any way.

This research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.

Please complete the booklet in the order it is presented.

You will need a pen and are allowed a calculator if required.

The time recorded at the beginning and end of each section will be from the stopwatch displayed on the screen.

Please solve each maths problem to the best of your ability and show all working out.

Please record your start and finish time for each section as soon as you finish as indicated on the paper.

If you change your mind about an answer to a question using a scale, cross it out and circle another one.

Once you have completed a section and filled in the time, do not go back and make any more changes.
Be aware that the scales do change in different sections of the booklet.

For the 16 questions following each section of maths problems, please refer to the following scales.

Q1→6:
1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7→16
0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case

Please answer the questions as honestly as possible.

All responses will remain confidential. You will not be identified.

Only the researcher will see the completed worksheets.

The subject co-ordinator will be informed of the maths results only.

Other data collected from the worksheets will be used solely for the purpose of the research.
Before you start, please complete the following details:

Name: _________________________________

Age: __________________________  Gender: Male / Female

Thank you for your participation in this experiment and contributing to my research.
Please do not begin until instructed
PART 1 – ABBREVIATED MATHS ANXIETY SCALE (AMAS)

This section contains a number of statements about mathematics.

You will be asked what you think about these statements.

There are no “right” or “wrong” answers. Your opinion is important.

Please rate each item in terms of how anxious you would feel during the event specified.

Use the following scale and record your answer by drawing a circle around the number that best describes your opinion.

1 = Low Anxiety
2 = Some Anxiety
3 = Moderate Anxiety
4 = Quite a bit of Anxiety
5 = High Anxiety

1. Having to use tables in the back of a math book.

![Rating Scale]

2. Thinking about an upcoming math test 1 day before.

![Rating Scale]
3. Watching a teacher work an algebraic equation on the board.

4. Taking an examination in a math course.

5. Being given a homework assignment of many difficult problems that is due in the next class meeting.

6. Listening to a lecture in math class.
7. Listening to another student explain a math formula.

8. Being given a “pop” quiz in math class.

PAPER 1

PART 2

MATHS PROBLEMS

SECTION A

Please do not begin until instructed
PART 2 - MATHS PROBLEMS: SECTION A

For each question, study the worked example and then answer the question in the solution space provided showing all your working out.

The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

Record Start Time: ____________________________

EXAMPLE

1. Solve for \( x \) \( x + 2 = 19 \)

\[
\begin{align*}
    x + 2 &= 19 - 2 \\
    x &= 17
\end{align*}
\]

(subtract 2 from each side)

QUESTION

Solve for \( y \) \( y - 4 = 12 \)

SOLUTION

______________________________

______________________________

______________________________
EXAMPLE

2. Solve for $a$  

\[ a + 4 = 15 \]

\[
\begin{align*}
  a + 4 - 4 &= 15 - 4 \\
  a &= 11
\end{align*}
\]

(subtract 4 from each side)

QUESTION

Solve for $y$  

\[ y + 7 = 24 \]

SOLUTION

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

EXAMPLE

3. Solve for $h$  

\[ h - 7 = 7 \]

\[
\begin{align*}
  h - 7 + 7 &= 7 + 7 \\
  h &= 14
\end{align*}
\]

(add 7 to each side)

QUESTION

Solve for $b$  

\[ b - 5 = 5 \]

SOLUTION

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
EXAMPLE

4. Solve for $b$ $b + 10 = -23$

\[
b + 10 - 10 = -23 - 10 \quad \text{(subtract 10 from each side)}
\]
\[
b = -33
\]

QUESTION

Solve for $x$ $x + 4 = -12$

\[
\text{SOLUTION}
\]

EXAMPLE

5. Solve for $y$ $y - 9 = -12$

\[
y - 9 + 9 = -12 + 9 \quad \text{(add 9 to both sides)}
\]
\[
y = -3
\]

QUESTION

Solve for $x$ $x - 5 = -8$

\[
\text{SOLUTION}
\]

Record Finish Time: ______________________
Please answer the following questions with regard to maths problems just completed in Section A.

These questions relate to two separate established rating scales.

**Please answer the questions honestly – there are no right or wrong answers.**

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning *not at all the case*) to 10 (meaning *completely the case*).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section A).

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

2. Rate the level of satisfaction with your performance on the task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

3. Rate the level of importance you place on this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10

| | | | | | | | | | |
8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
PAPER 1

PART 2

MATHS PROBLEMS

SECTION B

Please do not begin until instructed
PART 2 - MATHS PROBLEMS: SECTION B

For each question, study the worked example and then answer the question in the solution space provided showing all your working out.

The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

**Record Start Time:** ____________________________

**EXAMPLE**

1. Solve for \( x \) \( 5x - 3 = 12 \)

\[
\begin{align*}
5x - 3 & = 12 + 3 \\
5x & = 15 \\
5x ÷ 5 & = 15 ÷ 5 \\
x & = 3
\end{align*}
\]

**QUESTION**

Solve for \( x \) \( 3x - 4 = 8 \)

**SOLUTION**

__________________________________________

__________________________________________

__________________________________________

394
EXAMPLE

2. Solve for $x$ \hspace{1cm} 3x + 5 = 20

\[
\begin{align*}
3x + 5 &= 20 - 5 \\
3x &= 15 \\
3x + 3 &= 15 + 3 \\
x &= 5
\end{align*}
\]

(Subtract 5 from both sides)

(Divide both sides by 3)

QUESTION

Solve for $y$ \hspace{1cm} 2y + 1 = 25

SOLUTION

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

EXAMPLE

3. Solve for $a$ \hspace{1cm} 2a + 7 = -9

\[
\begin{align*}
2a + 7 &= -9 - 7 \\
2a &= -16 \\
2a + 2 &= -16 + 2 \\
a &= -8
\end{align*}
\]

(Subtract 7 from both sides)

(Divide both sides by 2)

QUESTION

Solve for $b$ \hspace{1cm} 4b – 5 = 11

SOLUTION

________________________________________

________________________________________

________________________________________

________________________________________

__________________________________________
EXAMPLE

4. Solve for \( x \) \( 3x – 5 = 13 \)

\[
\begin{align*}
3x - 5 &+ 5 = 13 + 5 \\
3x & = 18 \\
3x ÷ 3 & = 18 ÷ 3 \\
x & = 6
\end{align*}
\]

(Add 5 to both sides)

(Add 5 to both sides by 3)

QUESTION

SOLUTION

Solve for \( x \) \( 5x – 6 = 14 \)
EXAMPLE

5. Solve for $y$ \hspace{1cm} 6y + 7 = 4y + 13

\begin{align*}
6y - 4y + 7 &= 4y - 4y + 13 \\
2y + 7 &= 13 \\
2y + 7 - 7 &= 13 - 7 \\
2y &= 6 \\
\frac{2y}{2} &= \frac{6}{2} \\
y &= 3
\end{align*}

(Subtract 4$y$ from both sides)

(Subtract 7 from both sides)

(Divide both sides by 2)

QUESTION

Solve for $m$ \hspace{1cm} 2m + 4 = m + 9

SOLUTION

___________________________________________

___________________________________________

___________________________________________

___________________________________________

___________________________________________

___________________________________________

Record Finish Time: _________________________
Please answer the following questions with regard to maths problems just completed in Section B.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section B).

   1  2  3  4  5  6  7  8  9

   Extremely Low

   High

2. Rate the level of satisfaction with your performance on the task.

   1  2  3  4  5  6  7  8  9

   Extremely Low

   High

3. Rate the level of importance you place on this task.

   1  2  3  4  5  6  7  8  9

   Extremely Low

   High
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10
8. The task covered problems that I perceived as very complex.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

9. The task covered concepts that I perceived as very complex.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

10. The instructions and/or explanations during the task were very unclear.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

11. The instructions and/or explanations were, in terms of learning, very ineffective.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

12. The instructions and/or explanations were full of unclear language.

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
13. The task really enhanced my understanding of the topic covered.

0 1 2 3 4 5 6 7 8 9 10

14. The task really enhanced my knowledge and understanding of algebra.

0 1 2 3 4 5 6 7 8 9 10

15. The task really enhanced my understanding of the problems covered.

0 1 2 3 4 5 6 7 8 9 10

16. The task really enhanced my understanding of concepts.

0 1 2 3 4 5 6 7 8 9 10
PART 2 - MATHS PROBLEMS: SECTION C

For each question, study the worked example and then answer the question in the solution space provided showing all your working out.

The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

Record Start Time: ________________________________

EXAMPLE

1. Solve for \( b \) \( 2b - 13 = 11 - 4b \)

\[
2b + 4b - 13 = 11 - 4b + 4b \\
6b - 13 = 11 \\
6b - 13 + 13 = 11 + 13 \\
6b = 24 \\
6b + 6 = 24 + 6 \\
b = 4
\]

(Add 4\( b \) to both sides)

(Add 13 to both sides)

(Divide both sides by 6)

QUESTION

Solve for \( a \) \( 3a + 2 = 18 - a \)

SOLUTION

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

403
EXAMPLE

2. Solve for \( a \) \( 4(a + 1) = a + 10 \)

\[
\begin{align*}
4a + 4 &= a + 10 \\
4a - a + 4 &= a - a + 10 \\
3a + 4 &= 10 \\
3a + 4 - 4 &= 10 - 4 \\
3a &= 6 \\
3a ÷ 3 &= 6 ÷ 3 \\
a &= 2
\end{align*}
\]

(Expand brackets)
(Expand brackets)
(Add 4 to both sides)
(Subtract 4 from both sides)
(Divide both sides by 3)

QUESTION

Solve for \( x \) \( 3(x + 2) = x + 4 \)

\[ 3(x + 2) = x + 4 \]

\[ 3x + 6 = x + 4 \]

\[ 3x - x = 4 - 6 \]

\[ 2x = -2 \]

\[ x = -1 \]

SOLUTION

\[ 3(x + 2) = x + 4 \]

\[ 3x + 6 = x + 4 \]

\[ 3x - x = 4 - 6 \]

\[ 2x = -2 \]

\[ x = -1 \]

EXAMPLE

3. Solve for \( h \) \( 2(3h - 6) = 24 \)

\[
\begin{align*}
6h - 12 &= 24 \\
6h - 12 + 12 &= 24 + 12 \\
6h &= 36 \\
6h ÷ 6 &= 36 ÷ 6 \\
h &= 6
\end{align*}
\]

(Expand brackets)
(Add 12 to both sides)
(Divide both sides by 6)
QUESTION  
Solve for $x \quad 2(2x + 6) = 20$

SOLUTION

EXAMPLE

4. Solve for $y \quad 5y - 4 = 3(y - 6)$

$$5y - 4 = 3y - 18$$

$5y - 3y - 4 = 3y - 3y - 18$

$2y - 4 = -18$  

$2y - 4 + 4 = -18 + 4$  

$2y = -14$  

$2y + 2 = -14 + 2$

$y = -7$

QUESTION  
Solve for $x \quad 6x + 12 = 5(x + 5)$

SOLUTION

405
EXAMPLE

5. Solve for $x \quad x - 5 = 11 - 3x$

\[ x + 3x - 5 = 11 - 3x + 3x \]
\[ 4x - 5 = 11 \quad \text{(Add 3x to both sides)} \]
\[ 4x - 5 + 5 = 11 + 5 \]
\[ 4x = 16 \quad \text{(Add 5 to both sides)} \]
\[ 4x ÷ 4 = 16 ÷ 4 \]
\[ x = 4 \quad \text{(Divide both sides by 4)} \]

QUESTION

Solve for $x \quad x - 8 = 20 - 3x$

SOLUTION

\[ x - 8 = 20 - 3x \]
\[ x + 3x = 20 + 8 \]
\[ 4x = 28 \]
\[ x = 7 \]

Record Finish Time: _____________________

406
Please answer the following questions with regard to maths problems just completed in Section C.

These questions relate to two separate established rating scales.

**Please answer the questions honestly – there are no right or wrong answers.**

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning *not at all the case*) to 10 (meaning *completely the case*).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section C).

1 2 3 4 5 6 7 8 9

Extremely Low

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

Extremely Low

3. Rate the level of importance you place on this task.

1 2 3 4 5 6 7 8 9

Extremely Low
4. Rate the difficulty of the task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

**Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).**

7. The topic covered in the task was very complex.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.

END OF PAPER 1 – THANK YOU
APPENDIX L

Instructional Materials for
CLT Non-Compliant Condition
(Experiment 2)
PARTICIPANT BOOKLET  - Paper 1

INSTRUCTIONS TO PARTICIPANTS

The research does not form part of your assessment in any way.

This research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.

Please complete the booklet in the order it is presented.

You will need a pen and are allowed a calculator if required.

The time recorded at the beginning and end of each section will be from the stopwatch displayed on the screen.

Please solve each maths problem to the best of your ability and show all working out.

Please record your start and finish time for each section as soon as you finish as indicated on the paper.

If you change your mind about an answer to a question using a scale, cross it out and circle another one.

Once you have completed a section and filled in the time, do not go back and make any more changes.
Be aware that the scales do change in different sections of the booklet.

For the 16 questions following each section of maths problems, please refer to the following scales.

Q1\(\rightarrow\)6:

1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7 \(\rightarrow\) 16

0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case
Please answer the questions as honestly as possible.

All responses will remain confidential. You will not be identified.

Only the researcher will see the completed worksheets.

The subject co-ordinator will be informed of the maths results only.

Other data collected from the worksheets will be used solely for the purpose of the research.

Before you start, please complete the following details:

Name: __________________________________________________________

Age: ____________________ Gender: Male / Female

Thank you for your participation in this experiment and contributing to my research.
PART 1 – ABBREVIATED MATHS ANXIETY SCALE (AMAS)

This section contains a number of statements about mathematics.

You will be asked what you think about these statements.

There are no “right” or “wrong” answers. Your opinion is important.

Please rate each item in terms of how anxious you would feel during the event specified.

Use the following scale and record your answer by drawing a circle around the number that best describes your opinion.

1 = Low Anxiety
2 = Some Anxiety
3 = Moderate Anxiety
4 = Quite a bit of Anxiety
5 = High Anxiety

1. Having to use tables in the back of a math book.

2. Thinking about an upcoming math test 1 day before.

3. Watching a teacher work an algebraic equation on the board.
4. Taking an examination in a math course.

Low Anxiety     1   2   3   4   5 High Anxiety

5. Being given a homework assignment of many difficult problems that is due in the next class meeting.

Low Anxiety     1   2   3   4   5 High Anxiety

6. Listening to a lecture in math class.

Low Anxiety     1   2   3   4   5 High Anxiety

7. Listening to another student explain a math formula.

Low Anxiety     1   2   3   4   5 High Anxiety

8. Being given a “pop” quiz in math class.

Low Anxiety     1   2   3   4   5 High Anxiety


Low Anxiety     1   2   3   4   5 High Anxiety
PART 2 - MATHS PROBLEMS: SECTION A

For each of the following, answer the question in the solution space provided showing all your working out.
You may refer to the examples on the sheet provided for assistance.

Record Start Time: __________________________

SOLUTION

1. Solve for $y$  \[ y - 4 = 12 \]
   __________________________
   __________________________
   __________________________

2. Solve for $y$  \[ y + 7 = 24 \]
   __________________________
   __________________________
   __________________________
   __________________________

3. Solve for $b$  \[ b - 5 = 5 \]
   __________________________
   __________________________
4. Solve for $x$  \[ x + 4 = -12 \]

5. Solve for $x$  \[ x - 5 = -8 \]

Record Finish Time: ____________________________

Please answer the following questions with regard to maths problems just completed in Section A.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).
1. Rate the mental effort required to complete the task (that is, maths problems just completed in section A).

1 2 3 4 5 6 7 8 9

Extremely Low

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

Extremely Low

3. Rate the level of importance you place on this task.

1 2 3 4 5 6 7 8 9

Extremely Low

4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low
6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Extremely High

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10

8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

9. The task covered concepts that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

10. The instructions and/or explanations during the task were very unclear.

0 1 2 3 4 5 6 7 8 9 10
11. The instructions and/or explanations were, in terms of learning, very ineffective.

0 1 2 3 4 5 6 7 8 9 10

12. The instructions and/or explanations were full of unclear language.

0 1 2 3 4 5 6 7 8 9 10

13. The task really enhanced my understanding of the topic covered.

0 1 2 3 4 5 6 7 8 9 10

14. The task really enhanced my knowledge and understanding of algebra.

0 1 2 3 4 5 6 7 8 9 10

15. The task really enhanced my understanding of the problems covered.

0 1 2 3 4 5 6 7 8 9 10

16. The task really enhanced my understanding of concepts.

0 1 2 3 4 5 6 7 8 9 10
PAPER 1

PART 2

MATHS PROBLEMS

SECTION B

Please do not begin until instructed
PART 2 - MATHS PROBLEMS: SECTION B

For each of the following, answer the question in the solution space provided showing all your working out.

You may refer to the examples on the sheet provided for assistance.

Record Start Time: ____________________________

SOLUTION

1. Solve for \( x \) \[ 3x - 4 = 8 \]

2. Solve for \( y \) \[ 2y + 1 = 25 \]

3. Solve for \( b \) \[ 4b - 5 = 11 \]

4. Solve for \( x \) \[ 5x - 6 = 14 \]
5. Solve for \( m \): \[ 2m + 4 = m + 9 \]

____________________________________________________

____________________________________________________

____________________________________________________

Record Finish Time: __________________________

Please answer the following questions with regard to maths problems just completed in Section B.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section B).

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Low</th>
<th>Extremely</th>
<th>High</th>
</tr>
</thead>
</table>

2. Rate the level of satisfaction with your performance on the task.

1 2 3 4 5 6 7 8 9

<table>
<thead>
<tr>
<th>Extremely</th>
<th>Low</th>
<th>Extremely</th>
<th>High</th>
</tr>
</thead>
</table>
3. Rate the level of importance you place on this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td>Extremely High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Rate the difficulty of the task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td>Extremely High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Rate the level of anxiety you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td>Extremely High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Rate the level of engagement you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td>Extremely High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.
12. The instructions and/or explanations were full of unclear language.

13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
PAPER 1

PART 2

MATHS PROBLEMS

SECTION C

Please do not begin until instructed
PART 2 - MATHS PROBLEMS: SECTION C

For each of the following, answer the question in the solution space provided showing all your working out.
You may refer to the examples on the sheet provided for assistance.

Record Start Time: ________________________________

SOLUTION

1. Solve for \( a \)  
\[ 3a + 2 = 18 - a \]

2. Solve for \( x \)  
\[ 3(x + 2) = x + 4 \]
3. Solve for $x$ \[ 2(2x + 6) = 20 \]

4. Solve for $x$ \[ 6x + 12 = 5(x + 5) \]

5. Solve for $x$ \[ x - 8 = 20 - 3x \]
Please answer the following questions with regard to maths problems just completed in Section C.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section C).

2. Rate the level of satisfaction with your performance on the task.

3. Rate the level of importance you place on this task.
4. Rate the difficulty of the task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Extremely Low

**Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).**

7. The topic covered in the task was very complex.

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>
8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.

END OF PAPER 1 – THANK YOU
APPENDIX M

Product-oriented Worked Example Sheet for
CLT Non-Compliant Condition
(Experiment 2)
These worked examples are provided for you to refer to when answering the questions in the mathematics worksheet.

1. \(x + 2 = 19\)
   \[
x + 2 - 2 = 19 - 2
   \]
   \(x = 17\)

2. \(y + 6 = 4\)
   \[
y + 6 - 6 = 4 - 6
   \]
   \(y = -2\)

3. \(3a + 5 = 14\)
   \[
   3a + 5 - 5 = 14 - 5
   \]
   \(3a = 9\)
   \[
   3a ÷ 3 = 9 ÷ 3
   \]
   \(a = 3\)

4. \(2a + 7 = -9\)
   \[
   2a + 7 - 7 = -9 - 7
   \]
   \(2a = -16\)
   \[
   2a ÷ 2 = -16 ÷ 2
   \]
   \(a = -8\)

5. \(4(a + 1) = a + 10\)
   \[
   4a + 4 = a + 10
   \]
   \(4a - a + 4 = a - a + 10\)
   \[
   3a + 4 = 10
   \]
   \(3a + 4 - 4 = 10 - 4\)
   \[
   3a = 6
   \]
   \(3a ÷ 3 = 6 ÷ 3\)
   \[
   a = 2
   \]

6. \(2(3h - 6) = 24\)
   \[
   6h - 12 = 24
   \]
   \(6h ÷ 12 = 24 ÷ 12\)
   \[
   6h = 36
   \]
   \(6h ÷ 6 = 36 ÷ 6\)
   \[
   h = 6
   \]

7. \(5y - 4 = 3(y - 6)\)
   \[
   5y - 4 = 3y - 18
   \]
   \(5y - 3y - 4 = 3y - 3y - 18\)
   \[
   2y - 4 = -18
   \]
   \(2y - 4 + 4 = -18 + 4\)
   \[
   2y = -14
   \]
   \(2y ÷ 2 = -14 ÷ 2\)
   \[
   y = -7
   \]

8. \(x - 5 = 11 - 3x\)
   \[
   x + 3x - 5 = 11 - 3x + 3x
   \]
   \(4x - 5 = 11\)
   \[
   4x - 5 + 5 = 11 + 5
   \]
   \(4x = 16\)
   \[
   4x ÷ 4 = 16 ÷ 4
   \]
   \(x = 4\)
APPENDIX N

Consent Form

(Experiment 2)
Consent form for Tertiary Students

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

I have been given information about “Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions”. I have had the opportunity to ask any further questions I have regarding the research. This is part of a PhD degree supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford from the School of Education, Faculty of Social Science, at the University of Wollongong. I understand that my participation in this research is voluntary and I may withdraw at any time from the study.

I understand that if I consent to participate in this project I will be involved in one session of approximately 90 minutes at UOW during which time a series of maths tasks and related questions will be answered on worksheets provided. I understand that my contribution will be confidential and my name will not be used to identify my comments or work in the study. I understand that there are no potential risks or burdens associated with this study.

I understand that my participation in this research is voluntary and I am free to refuse to participate and I am free to withdraw from the research at any time. My refusal to participate or withdrawal of consent will not affect my relationship with the Faculty of Education at the University of Wollongong.

If I have any concerns regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, University of Wollongong on 4221 3386 or email rso-ethics@uow.edu.au.

I understand that the data collected from my participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication and conference presentations, and I consent for it to be used in that manner.

My signature below indicates that, having read the information provided above, I have decided to participate in the research.

Many thanks for your consideration of participating in this research.
STUDENT CONSENT

By signing below I am indicating my consent to participate in the research. I understand that the data collected from my participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication, and I consent for it to be used in that manner.

........................................  ........................................  ........................................
Signature of Student              Please PRINT name              Date

REVOCATION OF CONSENT

I hereby wish to WITHDRAW my consent for participation in the research described above and understand that such withdrawal WILL NOT jeopardise any treatment by, or my relationship with, The University of Wollongong.

........................................  ........................................  ........................................
Signature of Student              Please PRINT name              Date
APPENDIX O

Participant Information Sheet for Students
(Experiment 2)
Dear Student,

You are invited to participate in a study of Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions. The purpose of the research is to investigate the impact of providing worked examples in mathematics instruction on the performance of students of all abilities with materials of varying difficulty and how this interacts with student anxiety related to mathematics. You have been selected as a possible participant in this study because the instructional materials designed for the investigation are appropriate for students with knowledge of Stage 5 outcomes.

INVESTIGATORS
Deborah Chadwick
PhD candidate
dmc490@uowmail.edu.au

PRINCIPAL SUPERVISOR
Shirley Agostinho
School of Education
Faculty of Social Science
02-42215512
shirleyA@uow.edu.au

CO-SUPERVISOR
Sharon Tindall_ford
School of Education
Faculty of Social Science
02-42213553
sharontf@uow.edu.au

WHAT WE WOULD LIKE TO DO
If you decide to participate, you will be asked to complete a series of questionnaires and algebra worksheets based on the Year 9/10 NSW mathematics syllabus. The worksheet will require the transfer of your understanding of material and a measure of the number of correct responses will be made. In addition, you will be asked to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. Typical questions include: \(2x - 3 = 7\) and \(3y + 8 = 2y - 5\) for the maths task; Indicate the level of anxiety you experience listening to a lecture in a maths class and Rate the difficulty of this task for the questionnaire. The entire testing will require approximately 90 minutes and will take place at the University. We can foresee no risks for you as a result of participating in this study.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission, except as required by law. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers. In any publication, information will be presented in such a way that you will not be able to be identified.

The data collected from the results of the worksheets will be used for the purpose of the research identified in this letter. Research findings will be available to research participants at the completion of the study through the University of Wollongong.

PARTICIPANT INFORMATION SHEET FOR TERTIARY STUDENTS
ETHICS REVIEW AND COMPLAINTS
This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. Any concerns or complaints regarding this research may be directed to the UoW Ethics Officer (phone 4221 3386, email rso-ethics@uow.edu.au).

Your decision whether to not to participate will not prejudice your future relations with the University of Wollongong. If you decide to participate, you are free to withdraw your consent and to discontinue your participation at any time without prejudice.

Thank you for your interest in this study.

Deborah Chadwick
APPENDIX P

Additional Descriptive Statistics and Additional Findings

(Experiment 2)
Table P1

*Subjective Ratings of Satisfaction, Importance, Task Difficulty and Engagement*

<table>
<thead>
<tr>
<th>Variable</th>
<th>CCLA ((n = 45))</th>
<th>CCHA ((n = 51))</th>
<th>CNLA ((n = 51))</th>
<th>CNHA ((n = 48))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Low EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6.98</td>
<td>2.06</td>
<td>6.25</td>
<td>1.97</td>
</tr>
<tr>
<td>Importance</td>
<td>4.71</td>
<td>2.12</td>
<td>5.25</td>
<td>2.08</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.44</td>
<td>1.39</td>
<td>3.57</td>
<td>1.93</td>
</tr>
<tr>
<td>Engagement</td>
<td>4.40</td>
<td>1.95</td>
<td>5.49</td>
<td>1.94</td>
</tr>
<tr>
<td>Moderate EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>7.27</td>
<td>1.71</td>
<td>5.59</td>
<td>2.26</td>
</tr>
<tr>
<td>Importance</td>
<td>4.76</td>
<td>2.05</td>
<td>5.33</td>
<td>2.14</td>
</tr>
<tr>
<td>Difficulty</td>
<td>3.36</td>
<td>1.84</td>
<td>5.14</td>
<td>2.25</td>
</tr>
<tr>
<td>Engagement</td>
<td>4.84</td>
<td>2.02</td>
<td>5.67</td>
<td>1.83</td>
</tr>
<tr>
<td>High EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6.98</td>
<td>1.69</td>
<td>5.24</td>
<td>2.45</td>
</tr>
<tr>
<td>Importance</td>
<td>4.91</td>
<td>2.05</td>
<td>5.55</td>
<td>2.00</td>
</tr>
<tr>
<td>Difficulty</td>
<td>4.32</td>
<td>1.86</td>
<td>5.98</td>
<td>2.13</td>
</tr>
<tr>
<td>Engagement</td>
<td>5.02</td>
<td>1.69</td>
<td>5.78</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Table P2

*Descriptive Statistics - Intrinsic Cognitive Load*

<table>
<thead>
<tr>
<th>Element</th>
<th>Interactivity</th>
<th>EXPERIMENTAL CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CLT compliant (n = 124)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ICL Mean ((SD))</td>
</tr>
<tr>
<td>Low /30</td>
<td></td>
<td>5.42 (5.62)</td>
</tr>
<tr>
<td>Moderate /30</td>
<td></td>
<td>8.77 (7.90)</td>
</tr>
<tr>
<td>High /30</td>
<td></td>
<td>12.09 (8.58)</td>
</tr>
<tr>
<td>Total /90</td>
<td></td>
<td>26.29 (20.33)</td>
</tr>
</tbody>
</table>
Table P3

Descriptive Statistics - Germaine Cognitive Load

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL CONDITION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLT compliant n = 124</td>
<td>CLT non-compliant n = 127</td>
</tr>
<tr>
<td></td>
<td>GCL Mean (SD)</td>
<td>GCL Mean (SD)</td>
</tr>
<tr>
<td>Low (/40)</td>
<td>11.54 (10.22)</td>
<td>8.32 (7.71)</td>
</tr>
<tr>
<td>Moderate (/40)</td>
<td>11.69 (9.91)</td>
<td>8.74 (8.42)</td>
</tr>
<tr>
<td>High (/40)</td>
<td>12.30 (10.16)</td>
<td>9.32 (8.97)</td>
</tr>
<tr>
<td>Total (/120)</td>
<td>35.52 (27.85)</td>
<td>26.37 (22.98)</td>
</tr>
</tbody>
</table>

1. Part 3 Results: Additional Findings – Mental Effort

1.1 Mental Effort and Efficiency

Efficiency scores were calculated using mental effort and performance scores (refer to Section 4.3.5). The table below shows the efficiency scores for each condition, CLT compliant and CLT non-compliant, as well as for each group, incorporating instructional conditions and participant baseline maths anxiety.

Table P4

Mean Efficiency Scores Calculated using z Scores for Performance and Mental Effort Ratings

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC</td>
<td>CN</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-.0000004</td>
<td>-.0000007</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.0000023</td>
<td>-.0000002</td>
<td>.0000012</td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CCLA</td>
<td>CCHA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.0000007</td>
<td>.0000006</td>
<td>-.0000010</td>
</tr>
<tr>
<td></td>
<td>.0000016</td>
<td>.0000031</td>
<td>-.0000010</td>
</tr>
<tr>
<td></td>
<td>CNLA</td>
<td>CNHA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>.0000012</td>
<td>-.0000040</td>
<td>.0000012</td>
</tr>
<tr>
<td></td>
<td>-.0000013</td>
<td>.0000004</td>
<td></td>
</tr>
</tbody>
</table>
Efficiency measures were analysed in a 2 (Instruction Condition) x 3 (Element interactivity Condition) ANOVA. There was no significant difference in efficiency scores when comparing CLT compliant and CLT non-compliant conditions at low \((F(1,250) = 0, p = 1)\), moderate \((F(1,250) = 0, p = 1)\) and high \((F(1,250) = 0, p = 1)\) element interactivity. Efficiency measures were also analysed in a 4 (Instruction / Anxiety Group) X 3 (Element interactivity Condition) ANOVA. There was no significant difference in efficiency scores when comparing groups at low \((F(3,194) = 0, p = 1)\), moderate \((F(3,194) = 0, p = 1)\) and high \((F(3,194) = 0, p = 1)\) element interactivity.

### 1.2 Mental Effort and Task Difficulty

The increased subjective rating of cognitive load was reflected in data associated with participants’ subjective rating of task difficulty. As expected, at higher levels of element interactivity, participants reported higher levels of difficulty. Overall, participants’ rating of task difficulty was slightly higher for those using CLT compliant instructional materials (Mean = 12.22, \(SD = 5.50\)) compared to those using CLT non-compliant instructional materials (Mean = 11.43, \(SD = 5.32\)). However, this difference was not significant, \(F(1,249) = 1.32, p = .252\).

Data were analysed further based on participants’ baseline maths anxiety. Descriptive statistics for the four groups are presented in the table below.

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CCLA (n = 45)</td>
</tr>
<tr>
<td>Low</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.44 (1.39)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.36 (1.84)</td>
</tr>
<tr>
<td>High</td>
<td>4.32 (1.86)</td>
</tr>
<tr>
<td>Total</td>
<td>10.12 (4.52)</td>
</tr>
</tbody>
</table>

In both the CLT compliant condition and the CLT non-compliant condition, high anxiety participants consistently reported significantly higher difficulty ratings than low anxiety...
participants. The participant experimental group had a significant effect on the participants’ task difficulty ratings, \( F(3,191) = 11.948, p < .001 \).

As shown in the figure below, the increase in participants’ ratings of task difficulty followed a similar pattern as that of mental effort whereby the difficulty rating for tasks of moderate element interactivity compared to high element interactivity did not increase as much for the CLT compliant high anxiety group (CCHA) as it did for the CLT non-compliant high anxiety group (CNHA) (effect size: \( d = 0.38 \) compared to \( d = 0.47 \)).

![Figure P1. Graph of task difficulty ratings for experimental groups.](image)

Despite this, for high anxiety participants, there was no significant difference in task difficulty ratings between the CLT compliant condition and the CLT non-compliant condition at high element interactivity, \( F(191,3) = 1.107, p = .348 \).

2. Part 3 Results: Additional Findings - GCL and Participant Ratings of Task Satisfaction and Task Importance

Further analysis of participants’ reported germane cognitive load was conducted in terms of its relationship with participants’ rating of task importance and satisfaction. This was investigated in order to determine whether a learner was more inclined to invest germane resources into a task if it were deemed to be of greater importance. In addition, analysis may provide some insight into the effect of high anxiety on participants’ satisfaction with a completed task.
Participants reported the level of importance they placed on each task throughout the testing. A score between 1 and 9 was recorded on a likert scale for “Rate the level of importance of this task”. Participants also reported the level of satisfaction of their performance on each task throughout the testing. A score between 1 and 9 was recorded on a likert scale for “Rate the level of satisfaction with your performance on this task”. Descriptive statistics for the four groups are presented in the table below.

Table P6

<table>
<thead>
<tr>
<th>Group</th>
<th>MEAN SATISFACTION RATING</th>
<th>MEAN IMPORTANCE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low El</td>
<td>Mod El</td>
</tr>
<tr>
<td>CCLA</td>
<td>6.9778</td>
<td>7.2667(a)</td>
</tr>
<tr>
<td>CCHA</td>
<td>6.2549</td>
<td>5.5882(a)</td>
</tr>
<tr>
<td>CNLA</td>
<td>6.9608</td>
<td>6.5980</td>
</tr>
<tr>
<td>CNHA</td>
<td>6.5625</td>
<td>5.8750</td>
</tr>
</tbody>
</table>

Further analysis using t-tests of subjective ratings provided by participants related to satisfaction and importance of a task offered further insight into possible explanations. Participants with high baseline maths anxiety reported lower satisfaction but posit higher importance on a maths task of any level of difficulty compared to participants with low baseline maths anxiety. The use of CLT compliant materials further increased the perceived importance of a task but satisfaction with the task was only improved for low anxious students. The differences in these ratings were significant between those groups labeled in table above with the following results:

(a) $t(94) = 4.065, p < .001$
(b) $t(94) = 4.011, p < .001$
(c) $t(97) = 2.212, p = .029$
(d) $t(97) = 2.087, p = .040$
(e) $t(97) = 2.248, p = .027$

These ratings were reflected in the data for GCL; in addition to investing less germane resources than all other conditions, students with low baseline maths anxiety actually invested less germane resources at high element interactivity in comparison to their own investment at
lower levels of element interactivity. Without CLT compliant materials supporting their learning, the low level of importance placed on the task and their low satisfaction with the completed task, participants did not invest additional working memory resources to enhance their performance.

3. **Part 3 Results: Additional Findings – Perceived task Anxiety and Expertise**

Table P7

*Descriptive Statistics for Perceived Task Anxiety Ratings for Experts and Novices in CLT Compliant and CLT Non-Compliant Condition*

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>CLT compliant</th>
<th>CLT non-compliant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expert Mean (SD)</td>
<td>Novice Mean (SD)</td>
</tr>
<tr>
<td>Low</td>
<td>2.04 (1.74)</td>
<td>5.17 (2.20)</td>
</tr>
<tr>
<td>Moderate</td>
<td>2.44 (2.26)</td>
<td>6.06 (2.26)</td>
</tr>
<tr>
<td>High</td>
<td>2.76 (1.98)</td>
<td>6.78 (1.77)</td>
</tr>
</tbody>
</table>
APPENDIX Q

Ethics Approval Amendment
AMENDMENT APPROVAL LETTER

In reply please quote: HE14/108

Further Information Phone: 4221 3386

13 April 2016

Dear Ms Chadwick,

I am pleased to advise that the amendment dated 3/04/16 to the following Human Research Ethics application have been approved.

Ethics Number: HE14/108

Project Title: Providing Working Memory (WM) Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researchers: Ms Deborah Chadwick, Dr Shirley Agostinho, Dr Sharon Tindall-Ford

Amendment Approved: Repeat of experiment 1 with additional questions

Amendment Approval Date: 12 April 2016

Expiry Date: 28 May 2016

Please remember that in addition to reporting proposed changes to your research protocol the HREC requires that researchers immediately report:

- serious or unexpected adverse effects on participants immediately
- unforeseen events that might affect continued ethical acceptability of the project.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School and returned to the Research Services Office prior to the expiry date. If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,

Associate Professor Melanie Randle

Chair, UOW & ISLHD Social Sciences Human Research Ethics Committee
Ethics Unit, Research Services Office University of Wollongong NSW 2522 Australia Telephone (02) 4221 3386 Email: rso-ethics@uow.edu.au Web: www.uow.edu.au
APPENDIX R

Abbreviated Maths Anxiety Scale (AMAS)
(Experiment 3)
INSTRUCTIONS TO PARTICIPANTS

Please answer the questions as honestly as possible.

All responses will remain confidential. You will not be identified.

Only the researcher will see the completed worksheets and look at results. The data collected from the results of the worksheets will be used solely for the purpose of the research.

The research does not form part of your assessment in any way. Hopefully you may find doing this task helpful in some way.

The research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.

Thank you for your participation in this experiment and contributing to my research.

**Before you start, please complete the following details:**

First Name: ______________________________________________________________

Age: __________________________ Gender: Male / Female

Maths Class: ____________________________________________________________
PART 1 – ABBREVIATED MATHS ANXIETY SCALE (AMAS)

This section contains a number of statements about mathematics.

You will be asked what you think about these statements.

There are no “right” or “wrong” answers. Your opinion is important.

Please rate each item in terms of how anxious you would feel during the event specified.

Use the following scale and record your answer by drawing a circle around the number that best describes your opinion.

1 = Low Anxiety
2 = Some Anxiety
3 = Moderate Anxiety
4 = Quite a bit of Anxiety
5 = High Anxiety

1. Having to use tables in the back of a math book.

2. Thinking about an upcoming math test one day before.

3. Watching a teacher work an algebraic equation on the board.
4. Taking an examination in a math course.

5. Being given a homework assignment of many difficult problems that is due in the next class meeting.

6. Listening to a lecture in math class.

7. Listening to another student explain a math formula.

8. Being given a “pop” quiz in a math class.

APPENDIX S

Instructional Materials for
CLT Compliant Condition
(Experiment 3)
PARTICIPANT Paper 2

INSTRUCTIONS TO PARTICIPANTS

The research does not form part of your assessment in any way.

This research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.
Please complete the booklet in the order it is presented.
You will need a pen and are allowed a calculator if required.
Please solve each maths problem to the best of your ability and show all working out.
Please record your start and finish time for each section as soon as you finish as indicated on the paper. Once you have completed a section and filled in the time, do not go back and make any more changes.

If you change your mind about an answer to a question using a scale, cross it out and circle another one.

Be aware that the scales do change in different sections of the booklet.
For the 16 questions following each section of maths problems, please refer to the following scales.

Q1 → 6:
1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7 → 16
0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case
Please answer the questions as honestly as possible.

All responses will remain confidential. You will not be identified. Only the researcher will see the completed worksheets. Data collected from the worksheets will be used solely for the purpose of the research.

**Before you start, please complete the following details:**

Name: ______________________________________________________________

Age: ____________________ Gender: Male / Female

Thank you for your participation in this experiment and contributing to my research
MATHS PROBLEMS: SECTION A

For each question, study the worked example and then answer the question in the solution space provided showing all your working out. The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

Record Start Time: __________________________

EXAMPLE
1. Solve for \( x \) \( x + 2 = 19 \)
   \[ x + 2 - 2 = 19 - 2 \] (subtract 2 from each side)
   \[ x = 17 \]

   QUESTION
   Solve for \( y \) \( y - 4 = 12 \)
   ________________________________
   ________________________________

   SOLUTION

EXAMPLE
2. Solve for \( a \) \( a + 4 = 15 \)
   \[ a + 4 - 4 = 15 - 4 \] (subtract 4 from each side)
   \[ a = 11 \]

   QUESTION
   Solve for \( y \) \( y + 7 = 24 \)
   ________________________________
   ________________________________

   SOLUTION
EXAMPLE
3. Solve for $h$  $h - 7 = 7$

$$h - 7 + 7 = 7 + 7$$
$$h = 14$$

(question)

EXAMPLE
4. Solve for $b$  $b + 10 = -23$

$$b + 10 - 10 = -23 - 10$$
$$b = -33$$

(question)

EXAMPLE
5. Solve for $y$  $y - 9 = -12$

$$y - 9 + 9 = -12 + 9$$
$$y = -3$$

(question)
EXAMPLE

6. Solve for \( x \quad x + 20 = 5 \)

\[
x + 20 - 20 = 5 - 20 \quad \text{(subtract 20 from each side)}
\]
\[
x = -15
\]

QUESTION
Solve for \( y \quad y - 8 = 2 \)

SOLUTION

EXAMPLE

7. Solve for \( a \quad a + 3 = 10 \)

\[
a + 3 - 3 = 10 - 3 \quad \text{(subtract 3 from each side)}
\]
\[
a = 7
\]

QUESTION
Solve for \( y \quad y + 12 = 20 \)

SOLUTION

EXAMPLE

8. Solve for \( h \quad h - 4 = 7 \)

\[
h - 4 + 4 = 7 + 4 \quad \text{(add 4 to each side)}
\]
\[
h = 11
\]

QUESTION
Solve for \( b \quad b - 2 = 15 \)

SOLUTION

463
EXAMPLE

9. Solve for \( b \)  \( b + 8 = -17 \)

\[
b + 8 - 8 = -17 - 8
\]

\( b = -25 \)

(subtract 8 from each side)

QUESTION  SOLUTION

Solve for \( x \)  \( x + 6 = -10 \)

______________________________

______________________________

EXAMPLE

10. Solve for \( y \)  \( y - 11 = -16 \)

\[
y - 11 + 11 = -16 + 11
\]

\( y = -5 \)

(add 11 to both sides)

QUESTION  SOLUTION

Solve for \( x \)  \( x - 1 = -5 \)

______________________________

______________________________

Record Finish Time: ____________________________
Please answer the following questions with regard to maths problems just completed in Section A.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section A).

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

2. Rate the level of satisfaction with your performance on the task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

3. Rate the level of importance you place on this task.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely High</td>
</tr>
</tbody>
</table>
4. Rate the difficulty of the task.

1  2  3  4  5  6  7  8  9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.
8. The task covered problems that I perceived as very complex.

9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.
13. The task really enhanced my understanding of the topic covered.

0 1 2 3 4 5 6 7 8 9 10

14. The task really enhanced my knowledge and understanding of algebra.

0 1 2 3 4 5 6 7 8 9 10

15. The task really enhanced my understanding of the problems covered.

0 1 2 3 4 5 6 7 8 9 10

16. The task really enhanced my understanding of concepts.

0 1 2 3 4 5 6 7 8 9 10
MATHS PROBLEMS: SECTION B

For each question, study the worked example and then answer the question in the solution space provided showing all your working out.

The highlighted parts identify the key processes in the solution and these have been explained next to the worked example.

**Record Start Time:** ________________________________

**EXAMPLE**

1. **Solve for $b$** \(2b - 13 = 11 - 4b\)

\[
\begin{align*}
2b + 4b - 13 &= 11 - 4b + 4b \\
6b - 13 &= 11 \\
6b - 13 + 13 &= 11 + 13 \\
6b &= 24 \\
6b ÷ 6 &= 24 ÷ 6 \\
b &= 4
\end{align*}
\]

**QUESTION**

Solve for $a$ \(3a + 2 = 18 - a\)

________________________________________

________________________________________

________________________________________

________________________________________

469
EXAMPLE

2. Solve for \( a \quad 4(a + 1) = a + 10 \)

\[
\begin{align*}
4a + 4 &= a + 10 \\
4a - a + 4 &= a - a + 10 \\
3a + 4 &= 10 \\
3a + 4 - 4 &= 10 - 4 \\
3a &= 6 \\
3a ÷ 3 &= 6 ÷ 3 \\
a &= 2
\end{align*}
\]

(Expand brackets)

(Subtract \( a \) from both sides)

(Subtract 4 from both sides)

(Divide both sides by 3)

QUESTION SOLUTION

Solve for \( x \quad 3(x + 2) = x + 4 \)

EXAMPLE

3. Solve for \( h \quad 2(3h - 6) = 24 \)

\[
\begin{align*}
6h - 12 &= 24 \\
6h - 12 + 12 &= 24 + 12 \\
6h &= 36 \\
6h ÷ 6 &= 36 ÷ 6 \\
h &= 6
\end{align*}
\]

(Add 12 to both sides)

(Divide both sides by 6)
QUESTION
Solve for \( x \)

\[ 2(2x + 6) = 20 \]

SOLUTION

EXAMPLE

4. Solve for \( y \)

\[ 5y - 4 = 3(y - 6) \]

\[
5y - 4 = 3y - 18 \\
5y - 3y - 4 = 3y - 3y - 18 \\
2y - 4 = -18 \\
2y - 4 + 4 = -18 + 4 \\
2y = -14 \\
2y \div 2 = -14 \div 2 \\
y = -7
\]

QUESTION
Solve for \( x \)

\[ 6x + 12 = 5(x + 5) \]
EXAMPLE

5. Solve for $x$  
$x - 5 = 11 - 3x$

\[ x + 3x - 5 = 11 - 3x + 3x \]  
\[ 4x - 5 = 11 \]  
\[ 4x - 5 + 5 = 11 + 5 \]  
\[ 4x = 16 \]  
\[ 4x ÷ 4 = 16 ÷ 4 \]  
\[ x = 4 \]

QUESTION

Solve for $x$  
$x - 8 = 20 - 3x$

SOLUTION

EXAMPLE

6. Solve for $x$  
\[ \frac{x + 3}{7} = 3 \]

\[ 7 \times \frac{x + 3}{7} = 3 \times 7 \]  
\[ x + 3 = 21 \]  
\[ x + 3 - 3 = 21 - 3 \]  
\[ x = 18 \]
QUESTION
Solve for $x$ \[ \frac{x - 1}{3} = 4 \]

SOLUTION

EXAMPLE
7. Solve for $y$ \[ 6y + 7 = 4y + 13 \]

\[ 6y - 4y + 7 = 4y - 4y + 13 \] (subtract $4y$ from both sides)
\[ 2y + 7 = 13 \]
\[ 2y + 7 - 7 = 13 - 7 \] (subtract 7 from both sides)
\[ 2y = 6 \]
\[ 2y \div 2 = 6 \div 2 \] (divide both sides by 2)
\[ y = 3 \]

QUESTION
Solve for $m$ \[ 2m + 4 = m + 9 \]

SOLUTION
EXAMPLE

8. Solve for $x$  \[ 2x^2 = 32 \]

\[
\begin{align*}
2x^2 \div 2 &= 32 \div 2 \\
x^2 &= 16 \\
\sqrt{x^2} &= \sqrt{16} \\
x &= \pm 4
\end{align*}
\]

(divide both sides by 2) (find square root of both sides) (note positive and negative answer)

QUESTION  SOLUTION

Solve for $x$  \[ 5x^2 = 125 \]

\[
\begin{align*}
5x^2 &= 125 \\
x^2 &= \frac{125}{5} \\
x &= \pm \sqrt{25} \\
x &= \pm 5
\end{align*}
\]

EXAMPLE

9. Solve for $a$  \[ 4(a + 1) = a + 10 \]

\[
\begin{align*}
4a + 4 &= a + 10 \\
4a - a + 4 &= a - a + 10 \quad \text{(subtract $a$ from both sides)} \\
3a + 4 &= 10 \\
3a + 4 - 4 &= 10 - 4 \quad \text{(subtract 4 from both sides)} \\
3a &= 6 \\
3a + 3 &= 6 + 3 \quad \text{(divide both sides by 3)} \\
a &= 2
\end{align*}
\]
QUESTION
Solve for \( x \quad 3(x + 2) = x + 4 \)

SOLUTION

EXAMPLE
10. Solve for \( y \quad y^2 + 5 = 30 \)

\[
\begin{align*}
y^2 + 5 - 5 &= 30 - 5 \\
y^2 &= 25 \\
\sqrt{y^2} &= \sqrt{25} \\
y &= \pm 5
\end{align*}
\]

(subtract 5 from both sides)

(find square root of both sides)

(note positive and negative answer)

QUESTION
Solve for \( x \quad x^2 - 4 = 32 \)

SOLUTION

Record Finish Time: ____________________

475
Please answer the following questions with regard to maths problems just completed in Section B.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section B).

   1 2 3 4 5 6 7 8 9
   
   Extremely                   Extremely
   Low                         High

2. Rate the level of satisfaction with your performance on the task.

   1 2 3 4 5 6 7 8 9
   
   Extremely                   Extremely
   Low                         High

3. Rate the level of importance you place on this task.

   1 2 3 4 5 6 7 8 9
   
   Extremely                   Extremely
   Low                         High
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10

8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10
9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.

13. The task really enhanced my understanding of the topic covered.
14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.

END OF PAPER – THANK YOU
APPENDIX T

Instructional Materials for

CLT Non-Compliant Condition

(Experiment 3)
PARTICIPANT Paper 2

INSTRUCTIONS TO PARTICIPANTS

The research does not form part of your assessment in any way.

This research aims to investigate the link between maths instruction and anxiety. In this instance, anxiety is when you feel fear, uncertainty or a similar emotional reaction to a specific situation (such as doing maths).

Please write all your answers / responses in this booklet.
Please complete the booklet in the order it is presented.
You will need a pen and are allowed a calculator if required.
Please solve each maths problem to the best of your ability and show all working out.
Please record your start and finish time for each section as soon as you finish as indicated on the paper. Once you have completed a section and filled in the time, do not go back and make any more changes.

If you change your mind about an answer to a question using a scale, cross it out and circle another one.

Be aware that the scales do change in different sections of the booklet.
For the 16 questions following each section of maths problems, please refer to the following scales.

Q1→6:
1: extremely low
2: very low
3: moderately low
4: slightly low
5: neutral
6: slightly high
7: moderately high
8: very high
9: extremely high

Q7 → 16
0: not at all the case
2: very much not the case
3: moderately not the case
4: slightly not the case
5: neutral
6: slightly the case
7: moderately the case
8: very much the case
10: completely the case
Please answer the questions as honestly as possible.

All responses will remain confidential. You will not be identified. Only the researcher will see the completed worksheets. Data collected from the worksheets will be used solely for the purpose of the research.

Before you start, please complete the following details:

Name: ______________________________________________________________

Age: ______________________        Gender: Male / Female

Thank you for your participation in this experiment and contributing to my research.
MATHS PROBLEMS: SECTION A

For each of the following, answer the question in the solution space provided showing all your working out.

You may refer to the examples on the sheet provided for assistance.

Record Start Time: _______________________________________

SOLUTION

1. Solve for $y$  \[ y - 4 = 12 \]

   \[ y = 12 + 4 \]
   \[ y = 16 \]

2. Solve for $y$  \[ y + 7 = 24 \]

   \[ y = 24 - 7 \]
   \[ y = 17 \]

3. Solve for $b$  \[ b - 5 = 5 \]

   \[ b = 5 + 5 \]
   \[ b = 10 \]

4. Solve for $x$  \[ x + 4 = -12 \]

   \[ x = -12 - 4 \]
   \[ x = -16 \]
5. Solve for $x$ \[ x - 5 = -8 \]

6. Solve for $y$ \[ y - 8 = 2 \]

7. Solve for $y$ \[ y + 12 = 20 \]

8. Solve for $b$ \[ b - 2 = 15 \]

9. Solve for $x$ \[ x + 6 = -10 \]

10. Solve for $x$ \[ x - 1 = -5 \]

Record Finish Time: _______________________

484
Please answer the following questions with regard to maths problems just completed in Section A.

These questions relate to two separate established rating scales.

**Please answer the questions honestly – there are no right or wrong answers.**

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high).

Question 7 to Question 16 are measured on a scale from 0 (meaning *not at all the case*) to 10 (meaning *completely the case*).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section A).

   1 2 3 4 5 6 7 8 9

   | | | | | | | | | |

   Extremely | Low

2. Rate the level of satisfaction with your performance on the task.

   1 2 3 4 5 6 7 8 9

   | | | | | | | | | |

   Extremely | Low

3. Rate the level of importance you place on this task.

   1 2 3 4 5 6 7 8 9

   | | | | | | | | | |

   Extremely | Low

485
4. Rate the difficulty of the task.

1  2  3  4  5  6  7  8  9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1  2  3  4  5  6  7  8  9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0  1  2  3  4  5  6  7  8  9  10
8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

9. The task covered concepts that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10

10. The instructions and/or explanations during the task were very unclear.

0 1 2 3 4 5 6 7 8 9 10

11. The instructions and/or explanations were, in terms of learning, very ineffective.

0 1 2 3 4 5 6 7 8 9 10

12. The instructions and/or explanations were full of unclear language.

0 1 2 3 4 5 6 7 8 9 10

13. The task really enhanced my understanding of the topic covered.

0 1 2 3 4 5 6 7 8 9 10

487
14. The task really enhanced my knowledge and understanding of algebra.

15. The task really enhanced my understanding of the problems covered.

16. The task really enhanced my understanding of concepts.
MATHS PROBLEMS: SECTION B

For each of the following, answer the question in the solution space provided showing all your working out.
You may refer to the examples on the sheet provided for assistance.

Record Start Time: ________________________________

SOLUTION

1. Solve for \(a\) \[3a + 2 = 18 - a\]

2. Solve for \(x\) \[3(x + 2) = x + 4\]
3. **Solve for** $x \quad 2(2x + 6) = 20$

4. **Solve for** $x \quad 6x + 12 = 5(x + 5)$

5. **Solve for** $x \quad x - 8 = 20 - 3x$
6. Solve for $x$  \[
\frac{x - 1}{3} = 4
\]

7. Solve for $m$  \[2m + 4 = m + 9\]

8. Solve for $x$  \[5x^2 = 125\]
9. Solve for $x$  \[ 3(x + 2) = x + 4 \]

10. Solve for $x$  \[ x^2 - 4 = 32 \]

Record Finish Time: ______________________
Please answer the following questions with regard to maths problems just completed in Section B.

These questions relate to two separate established rating scales.

Please answer the questions honestly – there are no right or wrong answers.

Question 1 to Question 6 are measured on a scale from 1 (extremely low) to 9 (extremely high). Question 7 to Question 16 are measured on a scale from 0 (meaning not at all the case) to 10 (meaning completely the case).

1. Rate the mental effort required to complete the task (that is, maths problems just completed in section B).

1  2  3  4  5  6  7  8  9

Extremely  Extremely
Low  High

2. Rate the level of satisfaction with your performance on the task.

1  2  3  4  5  6  7  8  9

Extremely  Extremely
Low  High

3. Rate the level of importance you place on this task.

1  2  3  4  5  6  7  8  9

Extremely  Extremely
Low  High
4. Rate the difficulty of the task.

1 2 3 4 5 6 7 8 9

Extremely Low

5. Rate the level of anxiety you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

6. Rate the level of engagement you experienced while completing this task.

1 2 3 4 5 6 7 8 9

Extremely Low

Remember the scales change here - Respond to each of the questions on a scale from 0 to 10. (0 meaning not at all the case and 10 meaning completely the case).

7. The topic covered in the task was very complex.

0 1 2 3 4 5 6 7 8 9 10

8. The task covered problems that I perceived as very complex.

0 1 2 3 4 5 6 7 8 9 10
9. The task covered concepts that I perceived as very complex.

10. The instructions and/or explanations during the task were very unclear.

11. The instructions and/or explanations were, in terms of learning, very ineffective.

12. The instructions and/or explanations were full of unclear language.

13. The task really enhanced my understanding of the topic covered.

14. The task really enhanced my knowledge and understanding of algebra.
15. The task really enhanced my understanding of the problems covered.

[Blank scale with 0-10 ratings]

16. The task really enhanced my understanding of concepts.

[Blank scale with 0-10 ratings]

END OF PAPER – THANK YOU
APPENDIX U

Consent Form
(Experiment 3)
Consent form for Secondary Students and Parents

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

I have been given information about “Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions”. I have had the opportunity to ask any further questions I have regarding the research. This is part of a PhD degree supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford from the School of Education, Faculty of Social Science, at the University of Wollongong. I understand that my/child’s participation in this research is voluntary and I may withdraw at any time from the study without affecting my/child’s treatment at school in any way.

I understand that if I consent, participation in this project will involve two sessions of a total of 60 minutes in total at school during which time a series of maths tasks and related questions will be answered on worksheets provided. I understand that my/child’s contribution will be confidential and my/child’s name will not be used to identify my comments or work in the study. I understand that there are no potential risks or burdens associated with this study.

I understand that participation in this research is voluntary and I am free to refuse to participate and I am free to withdraw consent to participate in the research at any time. Refusal to participate or withdrawal of consent will not affect my/child’s relationship with the Faculty of Education at the University of Wollongong.

If I have any concerns regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, University of Wollongong on 4221 3386 or email rso-ethics@uow.edu.au.

I understand that the data collected from my/child’s participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication and conference presentations, and I consent for it to be used in that manner.
Many thanks for your consideration of participating in this research.

Please return the completed consent below and return to your class maths teacher by Friday 13th May 2016.

PARENT AND STUDENT CONSENT

By signing below I am indicating my consent to my/my child’s participation in the research. I understand that the data collected from my/my child’s participation will be used primarily for a PhD thesis, and will also be used in summary form for journal publication, and I consent for it to be used in that manner.

I give permission for my child……………………………… to participate in this research.

Parent/ Guardian Signature .......................... Date ........................

Name (please print) .................................................................

Child’s signature .................................................................

REVOCATION OF CONSENT

I hereby wish to WITHDRAW my consent for my/my child’s participation in the research described above and understand that such withdrawal WILL NOT jeopardise any treatment by, or my/my child’s relationship with, The University of Wollongong.

Signature of Student  Please PRINT name  Date

Signature of Parent  Please PRINT name  Date
APPENDIX V

Participant Information Sheets

(Experiment 3)

for

1. parent / guardian

2. student
PARTICIPANT INFORMATION SHEET FOR PARENT / GUARDIAN

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

Your child has been invited to participate in a study of Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions. My name is Deborah Chadwick and I am the principal researcher in the study described above. I am currently conducting a PhD with the School of Education, Faculty of Social Science, at the University of Wollongong; the research is being supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford. I hope to learn the impact mathematics instructions providing worked examples on the performance of students of all abilities with materials of varying difficulty and how this interacts with student anxiety related to mathematics. You child has been selected as a possible participant in this study because the instructional materials designed for the investigation are appropriate for students working towards Stage 4 outcomes.

If you decide to allow your child to participate, they will initially need to complete a brief questionnaire. This will be followed by completion of a series of questionnaires and algebra worksheets based on the Year 7/8 NSW mathematics syllabus. The worksheet will require the transfer of their understanding of material and a measure of the number of correct responses will be made. In addition, students will be required to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. The entire testing will require approximately 60 minutes (sessions of 15 minutes and 45 minutes) and will take place at the College. We can foresee no risks for your child as a result of participating in this study.

Any information that is obtained in connection with this study and that can be identified with your child will remain confidential and will be disclosed only with your permission, except as required by law. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers. In any publication, information will be presented in such a way that your child, their school and their teacher will not be able to be identified.

The data collected from the results of the worksheets will be used solely for the purpose of the research identified in this letter. Research findings will be available to research participants at the completion of the study through the University of Wollongong.
This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. Any concerns or complaints regarding this research may be directed to the UoW Ethics Officer (phone 4221 3386, email rso-ethics@uow.edu.au). Any complaint you make will be investigated promptly and you will be informed of the outcome.

Your decision whether to not to allow your child to participate will not prejudice you or your child’s future relations with the University of Wollongong. If you decide to allow your child to participate, you are free to withdraw your consent and to discontinue your child’s participation at any time without prejudice.

Thank you for your interest in this study.

Deborah Chadwick
PARTICIPANT INFORMATION SHEET FOR STUDENT

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

You are invited to participate in a study of Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions. My name is Deborah Chadwick and I am the principal researcher in the study described above. I am currently conducting a PhD with the School of Education, Faculty of Social Science, at the University of Wollongong; the research is being supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford. I hope to learn the impact mathematics instructions providing worked examples on the performance of students of all abilities with materials of varying difficulty and how this interacts with student anxiety related to mathematics. Your have been selected as a possible participant in this study because the instructional materials designed for the investigation are appropriate for students working towards Stage 4 outcomes.

If you decide to participate, initially you will need to complete a brief questionnaire. This will be followed by completion of a series of questionnaires and algebra worksheets based on the Year 7/8 NSW mathematics syllabus. The worksheet will require the transfer of your understanding of material and a measure of the number of correct responses will be made. In addition, students will be required to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. The entire testing will require approximately 15 minutes on the first occasion and approximately 45 minutes on the second occasion and will take place at the College. We can foresee no risks for you as a result of participating in this study.

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission, except as required by law. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers. In any publication, information will be presented in such a way that you will not be able to be identified.

The data collected from the results of the worksheets will be used solely for the purpose of the research identified in this letter. Research findings will be available to research participants at the completion of the study through the University of Wollongong.
This study has been reviewed by the Human Research Ethics Committee (Social Science, Humanities and Behavioural Science) of the University of Wollongong. Any concerns or complaints regarding this research may be directed to the UoW Ethics Officer (phone 4221 3386, email rso-ethics@uow.edu.au). Any complaint you make will be investigated promptly and you will be informed of the outcome.

Your decision whether to not to participate will not prejudice your future relations with the University of Wollongong. If you decide to participate, you are free to withdraw your consent and to discontinue your participation at any time without prejudice.

Thank you for your interest in this study.

Deborah Chadwick
APPENDIX W

Teacher Information Sheet
(Experiment 3)
INFORMATION LETTER TO HEAD OF DEPARTMENT / COURSE CONVENOR

Providing Working Memory Support for Anxious Students using Cognitive Load Theory Compliant Instructions

Researcher: Deborah Chadwick

Thank you very much for your interest in the above research conducted by the School of Education, Faculty of Social Science, University of Wollongong. The research is being conducted as part of my PhD supervised by Dr Shirley Agostinho and Dr Sharon Tindall-Ford.

The purpose of this study is to examine the interrelationship between working memory, cognitive load and anxiety. The research will specifically focus on instructional materials in the domain of mathematics and examine whether mathematics performance is improved for highly anxious learners as a result of the reduced working memory load associated with cognitive load theory compliant instructional material, as well as examine if there is a reduction in student anxiety levels.

The research will involve Year 8 mathematics students. Initially, students will complete a brief questionnaire related to maths anxiety. They will then be required to complete a series of algebra worksheets based on the Year 7/8 NSW mathematics syllabus and a measure of the number of correct responses will be made. In addition, students will be required to complete a short questionnaire following the task in order to provide subjective feedback regarding task difficulty and anxiety. The entire testing will require approximately 60 minutes (15 minutes for initial questionnaire and 45 minutes for maths worksheets) and will take place at the College. We can foresee no risks for your child as a result of participating in this study.

Participants will be provided with all materials required for the research. Teachers, students and parents will be provided with information sheets explaining the research and outlining the tasks involved in advance of their participation in the research. I plan to discuss and publish the results in order to share my findings with other education practitioners and researchers.

If there are any ethical concerns you can contact the Ethics Officer, Human Research Ethics Committee, University of Wollongong on (02) 4221 3386 or email rso-ethics@uow.edu.au. Should you require any further information please do not hesitate to contact members of the research team.

Yours sincerely,

Deborah Chadwick
APPENDIX X

Instructions for Teachers
(Experiment 3)
INSTRUCTIONS TO TEACHERS

• There are two different work booklets

• Students are to complete assigned worksheets – distributed randomly (2 groups).

• Please read through the front page of the booklets with the students.

• No further directions permitted once testing has begun.

Please reassure them of their anonymity and the fact that the completed data is seen / used by the researcher only.

INSTRUCTIONS TO STUDENTS

• On front cover please put first name and surname initial only.

• Worksheets are to be completed in order.

• Students may use calculators if necessary to eliminate calculation errors which are not part of the research data required.

• Time taken must be recorded at the beginning and end of each section – you may use the stopwatch on your phone or your watch to write actual times.

• Make sure time is recorded just before you start and as soon as you are finished.

• Once you have completed a section and filled in the time, do not go back and make any changes.

• Students may proceed at their own pace but need to record their time.

• All answers to be completed in the booklet.

• Please answer the maths questions to the best of your ability. Show all working.

• Please answer the questionnaires honestly – there are no right or wrong answers for these.

• 16 questions follow each section of maths problems. Please note the scale for the question changes.

Many thanks for your assistance and participation in this research.
APPENDIX Y

Additional Descriptive Statistics and Additional Findings

(Experiment 3)
Table Y1

**Descriptive Statistics - Intrinsic Cognitive Load**

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL CONDITION</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLT compliant $n = 43$</td>
<td>CLT non-compliant $n = 49$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ICL Mean ($SD$)</td>
<td>ICL Mean ($SD$)</td>
<td></td>
</tr>
<tr>
<td>Low (/30)</td>
<td>4.95 (5.61)</td>
<td>6.82 (5.99)</td>
<td></td>
</tr>
<tr>
<td>High (/30)</td>
<td>12.95 (7.21)</td>
<td>17.25 (6.84)</td>
<td></td>
</tr>
<tr>
<td>Total (/60)</td>
<td>17.91 (10.02)</td>
<td>24.08 (11.39)</td>
<td></td>
</tr>
</tbody>
</table>

Table Y2

**Descriptive Statistics - Germane Cognitive Load**

<table>
<thead>
<tr>
<th>Element Interactivity</th>
<th>EXPERIMENTAL CONDITION</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLT compliant $n = 43$</td>
<td>CLT non-compliant $n = 49$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GCL Mean ($SD$)</td>
<td>GCL Mean ($SD$)</td>
<td></td>
</tr>
<tr>
<td>Low (/40)</td>
<td>9 (10.21)</td>
<td>11.20 (10.18)</td>
<td></td>
</tr>
<tr>
<td>High (/40)</td>
<td>13.30 (9.85)</td>
<td>9.44 (8.80)</td>
<td></td>
</tr>
<tr>
<td>Total (/80)</td>
<td>22.30 (17.43)</td>
<td>20.75 (16.58)</td>
<td></td>
</tr>
</tbody>
</table>

Table Y3

**Subjective Ratings of Satisfaction, Importance, Task Difficulty and Engagement**

<table>
<thead>
<tr>
<th>Variable</th>
<th>CCLA ($n = 19$)</th>
<th>CCHA ($n = 13$)</th>
<th>CNLA ($n = 19$)</th>
<th>CNHA ($n = 16$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Low Ei</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>7.16</td>
<td>2.17</td>
<td>7.38</td>
<td>1.33</td>
</tr>
<tr>
<td>Importance</td>
<td>3.42</td>
<td>1.64</td>
<td>5.46</td>
<td>1.45</td>
</tr>
<tr>
<td>Difficulty</td>
<td>2.26</td>
<td>0.99</td>
<td>2.23</td>
<td>1.23</td>
</tr>
<tr>
<td>Engagement</td>
<td>4.39</td>
<td>2.09</td>
<td>4.54</td>
<td>1.81</td>
</tr>
<tr>
<td>High Ei</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>5.53</td>
<td>2.87</td>
<td>6.62</td>
<td>1.38</td>
</tr>
<tr>
<td>Importance</td>
<td>4.26</td>
<td>2.45</td>
<td>6.15</td>
<td>1.68</td>
</tr>
<tr>
<td>Difficulty</td>
<td>5.11</td>
<td>2.15</td>
<td>5.00</td>
<td>1.29</td>
</tr>
<tr>
<td>Engagement</td>
<td>4.28</td>
<td>1.64</td>
<td>5.08</td>
<td>1.66</td>
</tr>
</tbody>
</table>
Table Y4

Descriptive Statistics – Instructional Efficiency

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>Low El Mean (SD)</th>
<th>High El Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLT compliant</td>
<td>0.52 (0.62)</td>
<td>-0.46 (1.22)</td>
</tr>
<tr>
<td>CLT non-compliant</td>
<td>0.59 (1.07)</td>
<td>-0.53 (1.11)</td>
</tr>
</tbody>
</table>

1. Part 3 Results: Additional Findings - Mental Effort and Task Completion Time

Participants recorded the time taken to complete each task. Results indicated that students using CLT compliant materials used more time to complete tasks of low and high element interactivity. High anxiety participants using CLT compliant materials recorded a significantly higher completion time when completing tasks of low element interactivity. This suggests constructive use of the worked examples provided given their enhanced performance, a result of greater investment of germane resources (refer to Figure below). Despite the higher completion times, participants did not report higher mental effort ratings. At high element interactivity, there was no significant difference in task completion times between groups. Participants with low baseline maths anxiety using CLT non-compliant materials persisted with tasks of high element interactivity. However, this additional time, and mental effort, did not translate to an improvement in performance.

![Task Completion Time](image-url)

Figure Y1. Graph of task completion times with anxiety groupings.
Overall, completion time for tasks increased with increasing element interactivity and demonstrated the increasing cognitive load associated with more complex tasks. In the CLT compliant condition, task completion time was greatest for high anxiety participants, with CLT compliant high anxiety group (CCHA) the highest overall.