A Computer-Assisted Framework Based On The Bloom-Anderson Taxonomy For Teaching Mathematics In The Primary Years

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Declaration

I declare that this thesis is my own work and that to the best of my knowledge and belief, it contains no material that has been accepted or submitted to this or any other institution for an academic award or previously published or written by another person except where due reference has been made in the text.

Nasrin Moradmand  Date: 21/04/2014
Dedication

To my beloved husband Said and my darling daughter Sana.
Thanks for being there through it all.
LIST OF PUBLICATIONS AND EDUCATIONAL RESOURCES FROM THIS RESEARCH


Educational Resources:


My Maths Story software - Tools 1

My Maths Story software - Tools 2

My Maths Story - Tools 2, Hands on materials
ABSTRACT

Advances in Information and Communications Technologies (ICTs) have led to changes in teaching and learning in schools. In Australia, the integration of ICTs across the schooling system has become a priority. In the teaching of mathematics in the primary school years, educational multimedia software has the potential to provide successful teaching and learning experiences for both teachers and learners. However, few educational applications fit well in Australian primary school settings in that they are not considered to be pedagogically appropriate by teachers. This can be attributed to a disconnection between theory for designing educational applications and theory relating to the application of technology in classrooms, as well as a lack of alignment between technology, the curriculum and pedagogy. This study argues and demonstrates that the design and integration of educational interactive multimedia software should be based on pedagogical principles and general human-computer interaction principles, as well as educational theory, to design successful teaching and learning experiences. Consideration should be given to both the technical aspects of interactive software design and the pedagogical aspects of integration into the curriculum and teachers’ pedagogical beliefs and practices.

This study took place with the aim of designing and developing interactive multimedia educational software, based on a mathematics education framework, that meets the requirements of the Australian Curriculum to assist in the teaching of mathematics concepts in Australian primary school classrooms. The study presents a new educational framework, based on the Bloom/Anderson cognitive learning objectives, to guide the design and use of multimedia technology that enables the presentation of multiple representations and uses children’s literature for the teaching of mathematics.

The study also involved the selection of an Instructional System Design (ISD) model as a guideline for understanding educational objectives, and as a guide for the design and development of computer-based materials and tools to assist in the transition and evaluation of the intervention. With reference to the design and development of educational interactive multimedia software, the thesis argues that both the interactive systems design perspective and educational perspectives need to be considered. In the absence of a
universal methodology for the development of educational interactive multimedia software, the study involved the construction of a new model (IMDLC model), which is underpinned by cognitive theory and multimedia learning principles. Using the ISD model, the underpinning educational framework and the new software development model, it was possible to design and develop interactive multimedia educational software systems named My Maths Story.

The research study implementation and evaluation were conducted in two phases, where the second phase (Phase 2) was built on the results and experiences of the first phase (Phase 1). This study applied a mixed method approach to address the research questions. In total, 31 teachers within 17 different schools participated in the two phases of this study. In the second phase of the study, in absence of a suitable Australian mathematics concept storybook that met the requirements of participant teachers, the author of this thesis wrote and illustrated a new Australian mathematics storybook. As a result “Count on Me! A Mathematics Adventure Storybook” was written for the software. The process of implementation and the findings indicate that the My Maths Story multimedia application holds considerable potential for teaching mathematics in primary mathematics classrooms through storytelling and the use of multimedia technology. This research indicates that, when based on suitable pedagogical principles, the use of multimedia for teaching abstract subjects such as mathematics can provide successful teaching and learning experiences for both teachers and learners.

This thesis proposes a new development framework, which advocates an iterative approach in the design and implementation of educational applications. It is suggested by the researcher that the framework could be used or adapted to develop similar projects; researchers, educators, teachers, technology instructional designers and software developers could use or adapt the framework in the creation of new multimedia programs. The study makes a contribution to new knowledge in number of areas including: education contexts (for researchers, educators and teachers), computer software contexts (for educational software designer and developer) and instructional system design contexts (for technology instructional designers).
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TABLE OF CONTENT

LIST OF FIGURES xiv
LIST OF TABLES xvii

CHAPTER 1: INTRODUCTION 1
1.1. Contextual background 1
1.2. The research aims and questions 6
1.3. About the researcher 8
1.4. The structure of the thesis 10
1.5. Chapter conclusion 11

CHAPTER 2: LITERATURE REVIEW 13
2.1. Interactive technology in the teaching and learning process 13
  2.1.1. Interactive multimedia applications in teaching and learning 14
  2.1.2. The design of interactive multimedia applications for teaching and learning 20
  2.1.3. Integrating technology in the 21st century classroom 25
2.2. Teaching mathematics in the primary school 28
2.3. Pedagogy in mathematics 31
2.4. Existing computer-based mathematics applications and their pedagogical limitations 38
2.5. Statement of the problem 40
2.6. Chapter conclusion 41

CHAPTER 3: RESEARCH DESIGN AND METHOD 43
3.1. Research approach 43
3.2. Conceptual framework 47
3.3. Instructional system design 50
  3.3.1. Instructional design models 52
  3.3.2. ADDIE model process 53
3.4. Research procedure 57
  3.4.1. Selection of participants 58
  3.4.2. Tools and materials 62
6.2.2. Design 166
6.2.3. Development 174
6.2.4. Implementation 180
6.2.5. Evaluation and findings of Tools 2 188
6.3. Chapter conclusion 218

CHAPTER 7: DISCUSSION AND CONCLUSION 221
7.1. Overview of the research and the research questions 221
7.1.1. Research question 1 224
7.1.2. Research question 2 227
7.1.3. Research question 3 233
7.2. Limitations of the study 237
7.3. Recommendations 237
7.4. Concluding remarks and contributions 239
7.5. Conclusion 240

REFERENCES 243

APPENDIXES 259
Appendix A: Semi-structured interview 260
Appendix B1: Questionnaire 264
Appendix B2: Pre-service teachers questionnaire 267
Appendix C: Observation 270
Appendix D: Student feedback form 273
Appendix E: Qualitative codebook 274
Appendix F: Sample letter of invitation and a consent form 278
Appendix G: My Maths Story’s user guide documentsations 281
Appendix H: Australian Curriculum: Number and Algebra strands 297
Appendix I: “Count on Me!” A Mathematics Adventure Storybook 303
LIST OF FIGURES

Figure 2.1: The TPACK framework and its knowledge components (Koehler & Mishra, 2008)
Figure 2.2: The four levels of the SAMR model (Puentedura, 2011)
Figure 3.1: The convergent parallel mixed method from Research design: qualitative, quantitative, and mixed methods approaches (Creswell, 2013)
Figure 3.2: The study’s research design based on mixed methods approaches (Creswell, 2013)
Figure 3.3: Categories in the cognitive domain of Bloom’s Taxonomy (Anderson, et al., 2001)
Source: http://www.educationworld.com/a_curr/mathchat/mathchat026.shtml
Figure 3.4: Proposed educational framework
Figure 3.5: The conceptual ties between the Bloom/Anderson taxonomy and the proposed framework
Figure 3.6: Instructional system design components of My Maths Story applications
Figure 3.7: The ADDIE model of instructional system design
Figure 3.8: The ADDIE model in Phase 1 and 2 of the study
Figure 3.9: The different steps in the study’s procedure
Figure 3.10: a. The process of recruiting participant teachers for Phase 1 of the study,
b. the process of recruiting participants teachers for Phase 2 of the study
Figure 3.11: The questionnaire data organisation
Figure 3.12: The developed codebook for the questionnaire
Figure 3.13: The qualitative data analysis process (adapted from Creswell, 2013, p. 197)
Figure 3.14: Screen capture of the qualitative data analysis in Nvivo software
Figure 3.15: Process of qualitative data coding
Figure 4.1: Educational multimedia software development activities
Figure 4.2: Software Development Life Cycle (SDLC)
Figure 4.3: Waterfall SDLC
Figure 4.4: Proposed IMDLC Model
Figure 4.5: The waterfall SDLC and the IMDLC Model
Figure 4.6: Sample of storyboarding for Tools 1
Figure 4.7: Tools 1’s flowchart design
Figure 4.8: Sample of colours used in the interface design-Tools 2
Figure 4.9: Victorian Modern Cursive typography in Tools 1
Figure 4.10: Sample of icons design
Figure 4.11: The navigation system of the multimedia software
Figure 4.12: The screen structure of the interactive storybook software of Tools 1
Figure 4.13: a. The multimedia software’s production for Tools 2-Graphic production
Figure 4.13: b. The multimedia software’s production for Tools 2- Media production
Figure 4.13: c. The multimedia software’s production for Tools 2- Software programming
Figure 4.14: The study website and branding
Figure 4.15: The user guides documentation, a. Tools 1 user guide, b. Tools 2 user guide
Figure 4.16: Sample of teacher’s email in the maintenance stage
Figure 4.17: Summary of activities in the proposed IMDLC model
Figure 4.18: Interactive multimedia software tools in two phases of My Maths Story
Figure 5.1: “One is a Snail, Ten is a Crab”, a counting by feet book by April Pulley Sayre, Jeff Sayre, and Randy Cecil (2003)
Figure 5.2: “One is a Snail, Ten is a Crab” book: example of inside pages
Figure 5.3: Illustration of the Interactive Storybook software design strategies
Figure 5.4: Sample illustration of the Student Activity software
Figure 5.5: Sample illustration of the student Group Project software
Figure 5.6: Development phase, based on the IMDLC model: a. planning and conceptualisation, b. design and prototyping, c. production, d. testing and evaluation, e. deployment and maintenance
Figure 5.7: Evaluation by pre-service teachers and mathematics educators
Figure 5.8: Teachers using the tools in classrooms for demonstrating mathematics concepts
Figure 5.9: Students using the tools independently
Figure 5.10: Some examples of activities created in the Student Activity software
Figure 5.11: a. Student using the tools in pairs or small groups, b. a sample of mathematics world problem created in the Group Project software
Figure 5.12: A student feedback form
Figure 6.1: The cover and some example of inside pages of the “Count on Me!” book
Figure 6.2: Sample feedback for revision of the “Count on Me!” book
Figure 6.3: Sample illustrations of the Interactive Storybook software design strategies - the farm scene
Figure 6.4: Tools 2 - Student Activity software
Figure 6.5: Tools 2 - Student Group Project 1
Figure 6.6: Tools 2 - Student Group Project 2
Figure 6.7: Tools 2 development phase, based on the IMDLC model

Figure 6.8: a. “Count on Me!” hands on materials, b. “Count on Me!” book in two different sizes

Figure 6.9: Evaluation of Tools 2 by pre-service teachers and mathematics educators

Figure 6.10: Reading the interactive storybook

Figure 6.11: Teachers using the “Count on Me!” Interactive Storybook software - the farm setting

Figure 6.12: Teachers using the “Count on Me!” Interactive Storybook software - the shop setting

Figure 6.13: Teachers using the “Count on Me!” Interactive Storybook software - the carpentry setting

Figure 6.14: The use of the grid in the “Count on Me!” Interactive Storybook software

Figure 6.15: Teachers using the “Count on Me!” Interactive Storybook software - the bakery setting

Figure 6.16: a. Demonstration of time concept (analogue and digital clock), b. the use of the software's village map feature

Figure 6.17: Implementation of the Student Activity software to target a range of learning objectives

Figure 6.18: Sample uses of the Group Project 1

Figure 6.19: Sample uses of the Group Project 2

Figure 6.20: Children using the hands on materials of the Count on Me! tools for solving mathematics problems in small groups

Figure 7.1: Summary of links between the research questions, research activities, data collection and evaluation criteria in the research study

Figure 7.2: Instructional System Design as a bridge between education and computer software domains

Figure 7.3: A development process framework for the creation of educational interactive multimedia software
| Table 2.1: | Clark and Mayer’s six multimedia design principles (Clark & Mayer, 2011) |
| Table 3.1: | Summary of links between data collection instruments and technological evaluation criteria |
| Table 3.2: | The data collection questions link to different levels of the conceptual framework and other possible benefits of educational multimedia application |
| Table 3.3: | Sample from qualitative codebook |
| Table 4.1: | Summary of the components in the IMDLC’s planning and conceptualisation phase |
| Table 5.1: | Existing educational software’s technological and pedagogical limitations |
| Table 5.2: | Number and Place Value substrand of the Australian Curriculum (Year 1-Year 3) |
| Table 5.3: | Summary of the ADDIE design phase |
| Table 5.4: | Pre-service teachers’ and early primary mathematics educators’ suggestions and comments |
| Table 5.5: | Pre-service teachers’ responses to some questions about technical and pedagogical features of Tools 1 |
| Table 5.6: | Participant teachers’ responses to some questions about technical features of Tools 1 |
| Table 5.7: | Participant teachers’ requests for changes or the addition of new features |
| Table 5.8: | Participant teachers’ responses to some questions about pedagogical features of Tools 1 |
| Table 5.9: | Participant teachers’ pedagogical feature requests |
| Table 6.1: | Summary of findings and experiences from Phase 1 and actions for Phase 2 |
| Table 6.2: | Requested requirements and actions to meet the needs |
| Table 6.3: | Pre-service teachers’ responses to some questions about technical and pedagogical features of Tools 2 |
| Table 6.4: | Technological satisfaction evaluation of using Tools 2 |
| Table 6.5: | Summary of the teachers’ responses to applying cognitive learning objectives based on the Bloom/Anderson taxonomy |
| Table 6.6: | Participant teachers’ evaluation results on interactive multimedia technology for supporting mathematics pedagogies |
| Table 6.7: | Summary of teachers’ responses to questions relating to alignment to the Australian Curriculum of Tools 2 |
Chapter 1
INTRODUCTION

1.1. Contextual background

ICTs play a fundamental role in daily life and cannot be ignored or excluded from the educational context (DEEWR, 2008-2011; Yelland, 2001). Several studies claim that the use of new technologies in the classroom is necessary for providing opportunities for students to learn to operate in the 21st century. This argument is supported by Grimus (2000), who stated: “By teaching ICT skills in primary schools the pupils are prepared to face future developments based on proper understanding” (Grimus, 2000, p. 36). It has been raised as a concern among business leaders, educators, policymakers and parents that traditional school practices are not necessarily delivering the skills that students need. It appears that traditional education environments do not always seem to be appropriate for preparing students to be productive in the workplaces of the 21st century (Bingimlas, 2009; Yelland, 2001). Various research findings indicate that ICTs need to be integrated into education (Kim & Hannafin, 2011; Liu, 2011; Mumtaz, 2000; Schacter, 1999) so that children can learn in new and dynamic ways and be prepared for the challenges of life in the 21st century (Yelland, 2001).
Since the early 1980s, the place of ICTs in school has been changing from “learning about ICT” through “learning with ICT” to “learning through ICT” (Markauskaite, 2004). However, in many school settings, ICTs are still only used by teachers as tools for designing instruction material and delivery (such as using word processors for making worksheets or making PowerPoint presentations), not as learning devices or central components of teachers’ instructional programs (Liu, 2011; Serow & Callingham, 2011; Yelland, 2001).

A curriculum includes aims and objectives, subject matter or content, methods or procedures to teach content, as well as an evaluation or assessment component (Scott, 2008). Kozma (1994) asserted that schools needed to reform curriculum and pedagogy, since traditional forms of schooling were not designed to address the use of ICTs. In 2001, in Australia, the Department of Education, Training and Youth Affairs, stated that: “We are fitting new technologies into old curricula which were developed prior to their existence” (Yelland, 2001, p. 10).

Furthermore, Dawes (2001) indicated that new technologies have the potential to support education across the curriculum and can provide many opportunities for effective teaching and learning in ways not previously possible. These concerns essentially shifted the focus from technologies themselves towards a concern about the curriculum and instructional uses of digital tools and computer-based resources in teaching and learning. Earle (2002) supported this shift by stating:

“Integrating technology is not about technology – it is primarily about content and effective instructional practices. Technology involves the tools with which we deliver content and implement practices in better ways. Its focus must be on curriculum and learning. Integration is defined not by the amount or type of technology used, but by how and why it is used” (Earle, 2002, p. 8).

Several years later, new curricula have been developed in Australia, but teachers clearly still need support in modifying their pedagogies in order to use ICTs effectively (DEEWR, 2008-2011). In the USA, the National Council for the Teachers of Mathematics (NCTM) was successful in creating an agenda for reform of mathematics teaching, which has included the use of ICTs in the curriculum (Yelland, 2001). Furthermore, the National Technology
Leadership Summit, composed of teacher educator associations, stated that “ubiquitous computing will be a widespread force in schools by the end of the decade or sooner” (Bull, Bull, Garofalo, & Harris, 2002). This prediction has so far been accurate and computers and other ICTs are widespread in most schools in developed countries, including Australia; however, there is limited evidence to show that they are being used effectively in mathematics teaching and learning in primary schools.

In Australia, like other developed countries, the integration of ICTs across the curriculum has become a priority (DEEWR, 2008-2011; Phelps, Graham, & Watts, 2011). In 2008, the Joint Ministerial Statement on ICTs in Australian education and training: 2008-2011, acknowledged that Information and Communication Technologies “are enabling the transformation of the curriculum and changing the way learners and educators operate, learn and interact” (p, 1). It also has been stated that: “Developing the potential of all learners to be confident, informed citizens, equipped for success and for contributing to Australia’s society and economy, is central to Australia’s education and training goals”. In this statement, ministers agreed that:

“Australia will have technology enriched learning environments that enable students to achieve high quality learning outcomes and productively contribute to our society and economy” (Ministerial Council On Education, Employment, Training, & Affairs, 2008-2011).

The Council of Australian Governments (COAG), also recognised the important role of ICTs in schooling, and “the potential contribution of digital education, to the nation’s productivity” (DEEWR, 2008-2011). As a result, the Department of Education, Employment and Workplace Relations announced a ‘Digital Education Revolution’ (DER), which focused on ICTs in schools through four strands, including:

- **Leadership** – that ensures schools have a coordinated plan for the provision of infrastructure, learning resources and teacher capability to address the educational challenges of the 21st century;

- **Infrastructure** – access to digital teaching and learning resources and tools for processing information, building knowledge and for communication and collaboration;
• **Learning Resources** – that stimulate, challenge and assist students in achieving desired learning outcomes. These include collaborative and interactive activities as well as instructional and reference materials;

• **Teacher Capability** – teachers have the skills and tools to design and deliver programs that meet students’ needs and harness the benefits and resources of the digital revolution;

(DEEWR, 2008-2011, p. 5).

“The DER aims to contribute sustainable and meaningful change to teaching and learning in Australian schools that will prepare students for further education, training and to live and work in a digital world” (AITSL, 2012, p. 1).

Furthermore, for the first time in Australia, there are national curriculum frameworks that attempt to deliver national collaboration and standardisation of school education among Australian states and territories. The national curriculum frameworks cover the complete span of the Australian children school years (K-Year 12). The Early Years Learning Framework (EYLF) (Department of Education, Employment and Workforce Relations [DEEWR], 2009) for children in early childhood years (mostly aged 0-5 years) was implemented from 2010. Phase 1 of the implementation of the Australian Curriculum, Assessment and Reporting Authority (ACARA, n.d.) for children in the early years of primary school (mostly aged 5-8 years) began in early 2010. ACARA first developed the first series of curricular documents for the four learning areas of English, History, Mathematics and Science, as well as a set of General Capabilities, which included Literacy, Numeracy, Information and communication technology (ICT) capability, Critical and creative thinking, Personal and social capability, Ethical understanding and Intercultural understanding. In early 2013, Australia’s first national school curriculum was implemented among all states and territories.

ACARA and The Australian National Standards for Teachers (AITSL, 2012) both include a strong focus on the use of ICTs across the curriculum. As a result of this technology revolution, the pedagogical integration of ICTs across the curriculum has been highlighted, even in the early years of schooling. According to these documents, children need to be taught how to use ICTs effectively within and across the curriculum areas (ACARA, n.d.).
With reference to the mathematics learning area, the curriculum documents encourage teachers and students to use ICTs in the classroom to make calculations, draw graphs and interpret data, create spreadsheets, and practise with dynamic geometry software and computer algebra software in ways that were previously not possible (ACARA, n.d.). For example, in the Year 2 mathematics curriculum, children should learn to describe and draw two-dimensional shapes with and without digital technologies.

As noted above, the Australian Curriculum includes Information and Communication Competence as a ‘General Capability’. Thus, children develop ICT competence when they learn to:

- Investigate with ICT: using ICT to plan and refine information searches; to locate and access different types of data and information and to verify the integrity of data when investigating questions, topics or problems;
- Create with ICT: using ICT to generate ideas, plans, processes and products to create solutions to challenges or learning area tasks;
- Communicate with ICT: using ICT to communicate ideas and information with others adhering to social protocols appropriate to the communicative context (purpose, audience and technology);
- Operate ICT: applying technical knowledge and skills to use ICT efficiently and to manage data and information when and as needed;
- Apply appropriate social and ethical protocols and practices to operate and manage ICT;

(ACARA, n.d.)

To support this transformation, The Australian National Standards for Teachers (AITSL) also indicate that: “Teachers and school leaders have the greatest in-school influence on student achievement, so in order to build the ICT capacities of young Australians it is vital that teachers are equipped with the skills and tools to design and deliver technology-enriched teaching programs” (AITSL, 2012). The Australian Professional Standards for Teachers introduced seven Standards that outline what teachers need to know and be able
to do for effective teaching in 21st century schools, which result in improved educational outcomes for students. For example, in Standard 2, *Know the content and how to teach it*, the use of technology in the teaching and learning process is highlighted. Here, it is stated that teachers should "use effective teaching strategies to integrate ICT into learning and teaching programs to make selected content relevant and meaningful". In Standard 4, *Plan for and implement effective teaching and learning*, teachers are encouraged to select and/or create and use a range of resources, including ICT, to engage students in their learning (AITSL, 2012).

The implementation of the Australian Curriculum, which introduces the use of ICTs as a ‘General Capability’ across the curriculum, and the Australian government’s ‘Digital Education Revolution’ policy, bring the need for research in this area. Thus, as noted above, the issue is no longer whether ICTs should be integrated in existing classroom practices, but how to use them to transform teaching and create new opportunities for learning.

With a new Australian Curriculum and rapid changes in technology, there is an associated need to help and prepare teachers to implement any changes. Teachers need to adapt to change and embed suitable resources into their current mathematics pedagogies to keep pace with the new curriculums and technologies.

### 1.2. The research aims and questions

There is potential for children’s mathematical achievement to be improved in schools through the effective design and use of ICTs, especially computer-based and multimedia educational applications (Clements, 1993; Heid, 2005; Masalski, 2005; Saracho & Spodek, 2009). However, it is argued that not many educational applications fit well in Australian primary school settings to facilitate mathematics learning in a manner that is considered to be pedagogically appropriate by teachers (Baker, 2010; Mumtaz, 2000; Yelland, 2001). Hence, there is a need to design an educational framework based on accepted pedagogical approaches before developing any educational software and multimedia content.

This study is based on the assumption that to get good results from the integration of ICTs in education, any application’s design and development needs to be based on pedagogically
accepted principles, in terms of both learners’ and teachers’ needs. Thus, in the design
and development of educational interactive multimedia software, consideration to the
technological development of the multimedia application as well as to teaching and learning
theories and methods are required.

The aim of the study was to design an educational framework to guide the design and
use of multimedia technology in mathematics education in the primary school (K-Year 4).
The framework that resulted is based on contemporary pedagogical views of mathematics
education, as discussed in the literature review (Chapter 2), coupled with a cognitivist
framing, utilising the Bloom/Anderson taxonomy (Anderson, 2001; Bloom, 1956). The study
aimed to not only evaluate the usefulness of the developed interactive multimedia software
through extensive data collection and analysis, but also to describe the detailed process
of design, development and integration of such a complex system in the educational
context. The study aimed to explain the entire implementation and evaluation process of
the multimedia instructional materials for assisting in teaching and learning mathematics in
the Australian primary classrooms.

Few studies have explored and considered the technical aspects of interactive multimedia
software design and the pedagogical aspects of integration into the curriculum and
investigated teachers’ pedagogical beliefs and practices. Thus, the following questions
were composed to guide the study:

Q1. Can a framework based on the support of cognitive learning objectives through story be
used to inform the design and development of interactive multimedia software for primary
(K-Year 4) mathematics education?

Q2. How can educational interactive multimedia software, based on supporting cognitive
learning objectives through story, be developed to address the needs of both teachers and
students in the primary (K-Year 4) mathematics classroom?

Q3. Can the developed educational interactive multimedia software be incorporated into
K-Year 4 mathematics classrooms to support pedagogies and enhance mathematics
teaching?
1.3. About the researcher

The diversity and broad range of activities involved in this research (education, creative design, software development, mixed method research) makes it necessary that some information be provided about the researcher's background, skills, and motivation for conducting this study. Information is provided here in the form of a personal account.

I have a background in both Computer Science and Education. I graduated with a Master of Design in Digital Media, majoring in the design of educational media. I also have a Bachelor of Computer Engineering, a Training and Assessment (TAE) degree and a Diploma of Graphic/Web Design & Development. I have worked and taught (children and adults) in the Information Technology environment for ten years in both industry and in academic environments.

The area of education, and particularly education for young children, has interested me since my daughter started school and since I undertook postgraduate studies at the University of Adelaide majoring in design and development of educational media. Through voluntary work in schools, I noticed that teachers and young students face various technological challenges as well as challenges in the teaching and learning of abstract subjects such as mathematics. Since then, I have designed and developed a number of computer-based programs for children’s education. However, my activity in this area became more formal in 2011, when I joined the University of Western Australia (UWA) to undertake my PhD study in the School of Computer Science & Software Engineering and the Graduate School of Education.

I strongly believe that “mathematics is a language” (~Josiah Willard Gibbs) and we need to know how to learn and teach this language. As a parent myself, I understand that not every child wants to be a mathematician – however, all children can benefit from strong mathematical skills to aid in decision making and to increase opportunities in their lives. In today’s competitive world, many careers require a strong mathematical foundation and technology skills. My main aim and passion for this research has been to investigate and provide fitting teaching resources to teachers to enable better integration of ICTs into their classrooms and, in turn, to motivate, engage and inspire young children to explore mathematical concepts through technology and real world events and settings.
During my professional career, I have been involved in a number of research and implementation projects involving adult learning, children’s education, the education of people with learning difficulties and Aboriginal education. My passion for multimedia and education, along with my strong academic background and more than ten years of work in different role such as Software and Multimedia Developer, Education Advisor, and Media/Graphic Designer, gave me the confidence and capacity to work independently on the varied components of this research project.

Furthermore, to obtain a deeper understanding of the primary learning principles and mathematics pedagogies, at the beginning of this research study, I audited a number of courses at the University of Western Australia including, (EDUC8502) Teaching Mathematics in the Early Years and (EDUC5505) Teaching Mathematics in Middle and Upper Primary.

During the implementation of this research, I was inspired by the interest shown from students, especially young female students, not only in using the software for learning mathematics, but also in approaching the creator of the software. Students’ interests in talking to me as a female researcher and educational software designer regarding the process of development of the software and future career opportunities in this area were very encouraging. In most schools, I had group or individual conversations with young children regarding my professional computer science and education background and the process of design and development of the software using very informal and understandable language.

While working on this research, I was awarded the prestigious Google 2012 Anita Borg Award and Scholarship. Moreover, at the beginning of 2013, I was granted the Google CS4HS workshop fund to organise a workshop for Western Australia’s teachers, educators and ICT coordinators. This event was conducted for the first time in Western Australia in September 2013 for primary and high school teachers and educators. I have also been granted the Google CS4HS 2014 fund to run similar workshops in 2014.

Currently, I am mentoring number of young students for their future study and profession in technology, engineering and media education and it is pleasure to encourage children to not just be consumers of technology but also creators of technology.
1.4. The structure of the thesis

This thesis has seven chapters. Following the present introductory chapter, Chapter 2 reviews and summarises the literature relevant to the research study, followed by the statement of the research problem.

Chapter 3 outlines the research design and methodology. The chapter presents the research approach, conceptual framework and the instructional system design model used in this study. Chapter 3 also discusses the research paradigm in terms of the philosophical assumptions the researcher brings to the study and the research design. It describes the process of investigation, the methods of data collection, analysis and instrument validation that were used in the research. This chapter concludes with consideration of how various ethical concerns were addressed.

Chapter 4 presents a new interactive multimedia development model for use in the development process of the study’s tools. The chapter first provides an overview of the educational multimedia software development process and how it differs from other software development processes. The reasons for proposing and applying the new model are explained in this chapter, which also discusses the details of the various components of the model.

Chapter 5 presents the implementation process and findings of the first phase (Phase 1). The chapter describes the activities involved in planning, designing and implementing the first set of interactive multimedia software tools (Tools 1). The chapter presents the findings and an evaluation of the tools and lessons learnt from the first phase, which informed the design of the second phase (Chapter 6).

Chapter 6 presents the process of implementation and evaluation of Phase 2 of the study. This chapter first reviews the key findings of Phase 1 and then explains the process of design, development and implementation of the second set of interactive multimedia tools (Tools 2). Chapter 6 concludes with evaluation results and study findings of Phase 2.

Chapter 7 discusses the findings from the two phases of the study in order to answer
the research questions. This chapter is composed of two main sections. The first section provides an overview of the research and the research questions and discusses the study’s findings in relation to the research’s questions. The second part discusses the limitation of the study and makes suggestions and recommendations for further research and practice. This chapter concludes with the study’s significance and contributions to different context areas (education context, computer software context and instructional system design context).

1.5. Chapter conclusion

This chapter has presented the background and key issues that led to this research. The chapter has also introduced the aims of the study and research questions, as well as providing some information about the researcher’s background, skills, motivations and passion for this study. The following chapter will provide a critical review of the literature relevant to the study.
Chapter 2
LITERATURE REVIEW

The previous chapter presented background on the role of ICTs around the world and in the Australian education system. It also introduced the key issues that led to this research, the research aims and questions. Chapter 2 provides a critical review of the relevant literature related to the role of interactive technology, particularly interactive multimedia technology in the teaching and learning process. It explains the use of interactive computer-based applications in general, and multimedia applications in particular, and the impact of its use in teaching and learning, with particular emphasis on the mathematics learning area. Relevant literature is reviewed relating to four key areas: (a) interactive technology in teaching and learning; (b) teaching mathematics in the primary school; (c) pedagogies in mathematics, and; (d) existing computer-based mathematics applications and their pedagogical limitations. Through this review, a number of issues are raised about the design and use of computer-based applications in Australian primary schools.

2.1. Interactive technology in the teaching and learning process

Many studies have focused on technology integration in education and have concluded that interactive technology can have a positive effect on student learning (Kim & Hannafin,
Studies also indicate that, with the help of interactive technology, students are able to learn more deeply, test their ideas and review their understandings (Chang, Wu, Weng, & Sung, 2011; Clark & Mayer, 2011; Grabe & Grabe, 2007; Kozma, 2003; Mayer, 2003).

With regard to mathematics education, it has been claimed that the use of educational software can increase the mathematical achievement of children in pre-school and primary grades (Clements, 1993; Heid, 2005; Masalski, 2005; Saracho & Spodek, 2009). According to the research literature, the largest gains in mathematics learning so far appear to have been through the use of interactive mathematical application and practice software (Chang et al., 2011; Clements, 1987, 2002; Goodwin, 2008; Manches, O’Malley, & Benford, 2010; Yelland, 2001). Studies also indicate that through use of interactive technology, particularly interactive multimedia technology, students are able to engage more in activities, express their ideas, receive feedback on their performance, build new knowledge and revise their understandings (Chang et al., 2011; Clark & Mayer, 2011; Grabe & Grabe, 2007; Kozma, 2003; Mayer, 2003). These aspects of multimedia technology have encouraged many researchers to expand understanding of multimedia technology itself and how to design and develop multimedia applications that might be used as effective tools in the teaching and learning process (Clark & Mayer, 2003; Clark & Mayer, 2011; Doolittle, McNeill, Terry, & Scheer, 2005; S. Mishra & Sharma, 2005).

The next section of this chapter presents a definition of interactive multimedia technology and an overview of the role of this particular kind of software in the teaching and learning of abstract subjects, such as mathematics. It also explains a number of capabilities that multimedia technology can provide in the teaching and learning process. Some principles of design and development of educational interactive multimedia applications are also discussed.

### 2.1.1. Interactive multimedia applications in teaching and learning

Multimedia, simply defined as “multiple media” or the integration of multiple media elements (such as text, graphics, sound, animation, audio, video) in to one system as a whole that
may result in more benefits for the end users than any one of the media element can provide individually (S. Mishra & Sharma, 2005; Roblyer, Edwards, & Havriluk, 2006). A multimedia application (or application software) is defined as software that provides a sophisticated user interface (Engels, Sauer, & Neu, 2003). The sophisticated multimedia user interface can assist users to find information more effectively and increase knowledge in contact with multimedia data as well as enhanced entertainment value (Hoogeveen, 1997; Steinmetz & Nahrstedt, 2004).

Engels and Sauer (2003) provided a more comprehensive definition of multimedia applications:

“Multimedia applications can be defined as interactive software systems combining and presenting a set of independent media objects of diverse types that have spatio-temporal relationships and synchronization dependencies” (p. 2).

Interactive multimedia technology has the potential to contribute to the learning and teaching process through a number of capabilities, including: motivation, engagement, multiple representations, flexibility, and the development of higher order of thinking and problem solving skills.

2.1.1.1. Motivation

In relation to education, Bomia (1997) stated that, “Motivation refers to a student’s willingness, need, desire and compulsion to participate in, and be successful in, the learning process; it seeks to increase the factors that move a student toward becoming more involved in the class and the subject matter” (Bomia et al., 1997, p. 3). In other words, motivating a student means that the student is excited and will maintain interest in the activity or subject matter (Martin, 2005) during the teaching and learning process. In many studies, motivation has been mentioned as a key element in learning (M. Chang & Lehman, 2002; Crookes & Schmidt, 1991) and has been considered as one of the major factors of academic achievement and work productivity (Keller, 1979). Therefore, in teaching a concept, it is important to motivate students to make an effort and practise persistence in order to improve performance.
Research has shown that effective multimedia technology integration can impact student motivation and interest in learning and improve their motivation to develop skills and knowledge (Genc Ilter, 2009; Maushak, Chen, & Lai, 2001; Wiken, 2005). Multimedia technology can provide highly interactive environments that keeps students engaged with “nonstop actions, realistic sounds and vivid colours” while providing educational instruction (Maushak et al., 2001). Thus, multimedia technology, because of the interactive nature of the activities, brings content to life and stimulates learning. Also, it offer many options for students to learn information through multiple methods of presentation (Roblyer et al., 2006).

Furthermore, multimedia can enable the design of teaching materials using multiple methods (text, graphics, animation, audio and video) to gain the students’ attention and direct them to reach their learning goals. Studies of teachers’ beliefs also show that multimedia presentations help increase students’ interest, attention and curiosity first and then this increased attention can lead to increased motivation, which ultimately leads to better learning (Boster, Meyer, Roberto, & Inge, 2002; Wiken, 2005). Therefore, in the teaching and learning process, how the teacher puts multimedia technology to use in the classroom is a critical factor.

The ability to motivate and encourage students to be proactive leaners is believed to be one of the most important characteristics of multimedia applications (Clark & Mayer, 2011; Grabe & Grabe, 2007; McCarthy, 1989; Osborne & Collins, 2000). In the context of developing multimedia applications, the motivation of the users (teachers and students) to integrate multimedia application in their teaching and learning should be considered.

2.1.1.2. Engagement

Engagement refers to “the intensity and emotional quality of children’s involvement in initiating and carrying out learning activities” (Skinner & Belmont, 1993, p. 3). Student engagement overlaps with, but is not the same as, student motivation (Sharan, Shachar, & Levine, 1999; Skinner & Belmont, 1993). Students who are engaged show “sustained behavioral involvement in learning activities accompanied by a positive emotional tone” (Skinner & Belmont, 1993, p. 3).
“Engagement in training and educational presentations facilitates learning” (Webster & Ho, 1997). Clark and Mayer (2011) state that, “Regardless of delivery media, all learning requires engagement” (p. 16). According to Clark and Mayer (2011), engagement in learning can be achieved through two types of activity: behavioural and psychological. Behavioural engagement is action that a learner takes during an instructional experience through the use of an interactive program (Clark & Mayer, 2011), such as pressing the forward arrow, typing an answer in a text box, or verbally responding to an instructor’s question, while psychological engagement is “cognitive processing of content in ways that lead to acquisition of new knowledge and skills” (Clark & Mayer, 2011, p. 17).

Learners paying attention to relevant material, mentally organising it into a coherent representation, and integrating it with relevant prior knowledge are some cognitive process that lead to learning (Clark & Mayer, 2011). Activities such as self-explaining a complex visual, summarising a portion of a lesson, or taking a practice test can be included to a learning program to lead in achievement of psychological engagement (Clark & Mayer, 2011). Hence, both types of engagement can be applied to multimedia systems design and can help students reach learning goals and motivation (Clark & Mayer, 2011; Jacques, 1995; Webster & Ho, 1997).

Multimedia technologies can influence users’ engagement during teaching and learning processes through affording them control over the delivery of information and interactivity, which can lead to acquisition of new knowledge and skills. Therefore, development of multimedia applications that provide challenge, feedback, user control and variety can increase learner engagement (Cairncross & Mannion, 2001; Clark & Mayer, 2011; Webster & Ho, 1997).

### 2.1.1.3. Multiple representations

In mathematics education, Özgün-Koca (1998) defined multiple representations as “external mathematical embodiments of ideas and concepts to provide the same information in more than one form” (p. 1). Using multiple representations to demonstrate the same concepts by teachers may help learners benefit from the properties of each representation and then lead them to develop a better conceptual understanding of the subject being taught (Ainsworth,
The use of multiple representations is an essential part of mathematics education and appropriate use of them is a critical factor for effective teaching, together with accurate content knowledge (Capraro, Ozel, & Yetkiner, 2005; Ozgun-Koca, 1998).

Using multiple representations in the teaching and learning process can also help learners to process specific information in their preferred mode such as verbally, visually and through performing (doing). Bagui (1998) stated that multimedia “may have unique capabilities to facilitate learning because of the parallels between multimedia and the natural way people learn” (p. 4). Students learn in different ways and the ability to present and demonstrate information in more than one medium to support specific kinds of learning is one of the benefits of using multimedia program. Through combinations of text and audio, as well as still and motion visuals in multimedia applications, teachers can present, explain and communicate information to children to convey particular messages. For example, using a picture that illustrates a text based description or audio to present the same information can help teachers to target different learning abilities in their classroom. Therefore, multimedia technology can support multiple representations of the same parts of information or concept through variety of delivery format by using more than one medium element.

2.1.1.4. Flexibility

Collis and Moonen (2002) have defined flexibility as “a movement away from a situation in which key decisions about learning dimensions are made in advance by the instructor or institution, towards a situation where the learner has a range of options from which to choose with respect to these key dimensions” (p. 218). It has been claimed that flexibility in teaching and learning increases the choices available to both learners and teachers by “giving ample chance for students to practice their knowledge and skills (learning), but when they find difficulties, teachers require helping them to overcome their difficulties (teaching)” (Hamdan & Mattarima, 2012, p. 281). Flexibility enables teachers to create adaptable and differentiated instruction for a subject content, that addresses different learning abilities in the classroom. It also increases opportunities and options available to learners and gives them greater control over their learning through a variety of learning modes and interactions.
According to Collis and Moonen (2002), flexibility in teaching and learning can focus and improve different dimensions, including: flexibility in location, flexibility in program, flexibility in types of interactions, flexibility in forms of communication and flexibility in study materials. They also mentioned that these flexibilities can be increased through the use of different types of technology applications such as computer-based software.

Interactive multimedia applications offer great flexibility to both teachers and students in teaching and learning processes; it offers flexibility in the use of various formats in presenting content and individual approaches to learning at a time and place convenient to users (Cairncross & Mannion, 2001; Clark & Mayer, 2011; Roblyer et al., 2006). Multimedia technology allows teachers to modify an application according to their classroom needs as well as offering them the flexibility to present their curriculum in an innovative manner (Cairncross & Mannion, 2001; Clark & Mayer, 2011). Teachers also can facilitate active approaches to learning through involving the students in activities, to motivate them in their learning and to provide them with many ways to express their ideas and present their information and understanding. In the context of developing educational multimedia applications, the identification and inclusion of multiple presentation formats and a variety of different learning activities, which offer flexibility and user control over the presentation of information and interactivity, need to be carefully considered.

2.1.1.5. Development of higher order thinking and problem solving skills

Higher order thinking skills can be defined as “cognitive skills that allow students to function at the analysis, synthesis and evaluation” (or analysing, evaluating and creating (Anderson et al., 2001) levels of Bloom’s taxonomy (Hopson, Simms, & Knezek, 2002, p. 110). Higher order thinking and problem solving skills involve the ability to reflect on the learning experience and enable learners to “apply their content knowledge in a variety of ways, leading to innovation and deeper understanding of content domain” (Cradler, McNabb, Freeman, & Burchett, 2002, p. 47).

Kelman (1990) stated that using computer technology can help to improve higher order thinking. Studies in multimedia learning show that some of the most significant gains arising from the use of these tools are related to creative thinking, higher order thinking and
problem solving (Cradler et al., 2002; Gokhale, 1996; Robin, 2008). According to Cradler et al. (2002), when students use technology tools such as multimedia applications, they learn to “convert data to information and transform information into knowledge” (p. 48). They support this assertion, thus:

“Research and evaluation shows that technology tools for constructing artifacts and electronic information and communication resources support the development of higher-order thinking skills” (p. 48).

2.1.2. The design of interactive multimedia applications for teaching and learning

The mentioned capabilities of multimedia applications highlight the potential of creating educational environments to support better teaching and learning processes. However, this potential may not be realised due to the complexity of educational interactive multimedia applications environments (Cairncross & Mannion, 2001; Clark & Mayer, 2011). According to Clark and Mayer (2011), one of the challenges in multimedia learning design is to build learning experiences in ways that are compatible with human learning processes; instructional methods must support these processes in order to be effective.

Multimedia includes user interaction and exploration (Clark & Mayer, 2011; Ivers & Barron, 2003). Mishra and Sharma (2005) argued that an efficient interaction in educational multimedia design should create a desire to go on and find out more about learning objectives not demand that time in spent learning the actual technology (S. Mishra & Sharma, 2005). On the other hand, they stated, “[t]he prettiest designs may not be the simplest, nor the easiest to use”. Also, a multimedia system product should behave in a consistent manner. Consistency reduces learning time and reduces chances of surprises; increased familiarity translates into increased productivity (Clark & Mayer, 2011; Galitz, 2007).

It has been found that working memory and cognitive load have a substantial role in the development of comprehension and performance (Doolittle et al., 2005). Cognitive load refers “to the working memory demands implicitly and explicitly created by instruction and how these demands affect the learning process” (Doolittle et al., 2005, p. 185). Research
indicates that, when instruction is in the form of multimedia, the relationship between cognitive load, working memory, and instruction is especially significant (Doolittle et al., 2005; Mayer, 2003). This is because a poorly designed multimedia task results in increased cognitive load, which is a load that exceeds the processing capacity of the cognitive system (Clark & Mayer, 2011) and, therefore, decreased learning. Thus, the potential for cognitive overload is a central challenge for designers and developers of any educational multimedia application (Clark & Mayer, 2011; Doolittle et al., 2005).

Clark and Mayer’s contributions to understanding how the cognitive processes of interpreting visual and auditory information can affect learning have resulted in a set of principles for educational multimedia production, namely: Contiguity, Modality, Redundant, Coherence, Personalisation and Segmenting (Clark & Mayer, 2011). These principles are outlined below.

The Contiguity principle advises the designer to place words next to the part of the corresponding image they describe and to keep the need to scroll to a minimum. Presenting text and graphics in an integrated fashion rather than presenting the same information separately is claimed to result in learning gains. Reducing the need to search for the graphical elements that correspond to words allows the user to devote less cognitive resources towards understanding the materials (Clark & Mayer, 2011).

The Modality principle suggests that words should be presented as speech rather than on-screen text when it is feasible. Technical constraints (for example, size of audio file and production time) on the use of audio in multimedia may lead designers and media producers to rely on text to present content and describe visuals. However, there is empirical evidence to show that presenting words in audio rather than on-screen text to describe graphics can result in significant learning gains (Clark & Mayer, 2011; Doolittle et al., 2005). To explain the modality principle in the cognitive learning theory of multimedia, Clark and Mayer (2011) state:

“The psychological advantage of using audio presentation is a result of the incoming information being split across two separate cognitive channels—words in the auditory channel and pictures in the visual channel—rather than concentrating both words and pictures in the visual channel” (p. 115).
Redundant on-screen text in a multimedia application occurs when graphics, audio narration and on-screen text are presented in which the audio narration repeats the existing text (Clark & Mayer, 2011). In this case, the printed text (the on-screen text) is redundant with the spoken text (the narration or audio). The redundancy principle posits that people learn better from concurrent graphics and audio rather than from concurrent graphics, audio, and on-screen text. “In general, do not add printed text to a narrated graphic. The psychological advantage of presenting words in audio alone is that you avoid overloading the visual channel of working memory” (Clark & Mayer, 2011, p. 133).

According to the Coherence principle, designers of multimedia applications need to avoid adding material that does not support the instructional goal. It is a very important principle, because it is commonly violated, is straightforward to apply, and can have a strong impact on learning (Clark & Mayer, 2011; Doolittle et al., 2005). This principle encourages the exclusion rather than inclusion of extraneous information in the form of background sound, added text, and added graphics (Clark & Mayer, 2011).

“The theoretical rationale against adding music and sounds to multimedia presentations is based on the cognitive theory of multimedia learning, which assumes that working memory capacity is highly limited. Background sounds can overload and disrupt the cognitive system, so the narration and the extraneous sounds must compete for limited cognitive resources in the auditory channel. When learners pay attention to sounds and music, they are less able to pay attention to the narration describing the relevant steps in the explanation” (Clark & Mayer, 2011, p. 156-157).

The Personalisation principle supports using a conversational style of writing (including using first- and second-person language) and a friendly human voice rather than formal style of writing to present information.

“By emphasizing the personal aspects of the training [learning]—by using words like “you” and “I”—you convey a message that training [learning] is not serious” (Clark & Mayer, 2011, p. 183).

The use of on-screen pedagogical agents (on-screen coaches or tutors) and making the
author visible (giving a personal voice to the text) to the learner is found to be effective in the learning process (Clark & Mayer, 2011). This can promote learners’ motivation and deeper engagement with the learning materials. Less experienced learners are more likely to benefit from the personalisation principle when the amount of personalisation is modest enough to not detract from the lesson (Clark & Mayer, 2011; Moreno, Mayer, & Lester, 2000).

Research has shown that people work harder to understand material when they feel they are in a conversation with a partner, rather than simply receiving information (Beck, McKeown, Sandora, Kucan, & Worthy, 1996). Consequently, Clark and Mayer stated:

“Using conversational style in a multimedia presentation conveys to the learners the idea that they should work hard to understand what their conversational partner (in this case, the course narrator) is saying to them. In short, expressing information in conversational style can be a way to prime appropriate cognitive processing in the learner” (p. 184).

The personalisation principle also strongly suggests that people learn better from narration by a human voice rather than a machine voice, and that the characteristics of the speaker’s voice can have a strong impact on how people respond to computer-based communications (Clark & Mayer, 2011; Nass & Brave, 2005). There is also some evidence that people learn better from a human voice with a standard accent rather than a foreign accent (Mayer, Sobko, & Mautone, 2003) and learn better from female narrations of maths lessons, which tend to be male-stereotypic subjects (Linek, Gerjets, & Scheiter, 2010).

Finally, the Segmenting principle is about the situation through which learners must engage in learning of complex materials. Segmenting is a technique that breaks a lesson into manageable segments to prevent overloading learners’ cognitive systems (Clark & Mayer, 2011).

“When an unfamiliar learner receives a continuous presentation containing a lot of interrelated concepts, the likely result is that the cognitive system becomes overloaded—too much essential processing is required. In short, the learner does not have sufficient cognitive capacity to engage in the essential processing required to understand the material” (Clark & Mayer, 2011, p. 210).
These six principles informed this study’s multimedia educational software design, and are summarised in Table 2.1.

<table>
<thead>
<tr>
<th>Principles</th>
<th>Descriptions</th>
</tr>
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| Contiguity | Principle 1: place printed words near corresponding graphics  
- Avoid separation of text and graphics on scrolling screens  
- Avoid separation of feedback from questions or responses  
- Avoid separating lesson screens with linked windows  
- Avoid presenting exercise directions separate from the exercise  
- Avoid displaying captions at the bottom of screens  
- Avoid simultaneous display of animations and related text  
- Avoid using a legend to indicate the parts of a graphic  
Principle 2: synchronise spoken words with corresponding graphics  
- Avoid separation of graphics and narration through icons  
- Avoid separation of graphics and narration in a continuous presentation |
| Modality | Present words as speech rather than on-screen text |
| Redundancy | Explain visuals with words in audio or text: not both  
Principle 1: do not add on-screen text to narrated graphics  
Principle 2: consider adding on-screen text to narration in special situations |
| Coherence | Principle 1: avoid multimedia lesson with extraneous audio  
Principle 2: avoid multimedia lessons with extraneous graphics  
Principle 3: avoid multimedia lessons with extraneous words |
| Personalization | Principle 1: use conversational rather than formal style  
Principle 2: use effective on-screen coaches to promote learning  
Principle 3: make the author visible to promote learning |
| Segmenting | Break a continuous lesson into bite-size segments |

It has been argued that for any design to be successful, its design must be based on the needs and interests of users, and their limitation and capabilities, as well as the context in which the product will be used (Norman, 2002). Thus, in the case of educational interactive multimedia design, consideration to the technological development of the multimedia
application as well as to teaching and learning theories and methods is required. Teaching pedagogies and teachers’ beliefs about integrating technology in their classroom to address their curriculum should be considered.

The next section discusses teachers’ technological pedagogical content knowledge, their beliefs and the barriers they experience, as well as the impact of these beliefs and barriers on the design and use of interactive multimedia applications in classrooms.

2.1.3. Integrating technology in the 21st century classroom

A growing body of research indicates that using technology in appropriate ways has extensive pedagogical affordances and great potential for transforming the teaching and learning environment (Angeli & Valanides, 2009; Atweh & Goos, 2011; Dawes, 2001; Dede, 1998; Kim & Hannafin, 2011; Kozma, 2003; Liu, 2011; Mumtaz, 2000; Schacter, 1999). However, technology integration is no longer related to just knowing the computer-based technology, but how to use technology to transform teaching and to create new learning opportunities for students (Angeli & Valanides, 2009; Balanskat, Blamire, & Kefala, 2006; Morehead & LaBeau, 2005). An important contribution to this issue is found in the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2008), which describes the types of teacher knowledge required to teach effectively with technology. This framework has been developed to assist teachers think about their practices and how they can connect their technological, pedagogical and content knowledge in ways that might allow innovative practices and hence enhance student learning.

“...at the heart of good teaching with technology are three core components: Content, Pedagogy & Technology. Equally important are the relationships between these three components. It is the interactions, between and among these components, playing out differently across diverse contexts, that account for the wide variations seen in educational technology integration" (P. Mishra & Koehler, 2008, p. 3).

TPACK involves content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (P. Mishra & Koehler, 2008) required to teach in technology rich environments
(Figure 2.1). In the current study, content knowledge is associated with the primary school mathematics curriculum. Pedagogical knowledge includes learning theories and instructional methods, and technological knowledge includes the knowledge of how to use technology-based tools (in this case, interactive multimedia software) and the ability to adapt the novel technologies for delivering content and implementing practices in better ways.

Figure 2.1. The TPACK framework and its knowledge components (Koehler & Mishra, 2008)

TPACK goes beyond considering the three main components of content, pedagogy and technology as constructs. All possible interactions between any two constructs, namely, pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) are equally important for the effective use of technology in teaching and learning (P. Mishra & Koehler, 2008). With respect to TCK, Mishra & Koehler (2006) stated, “Teachers need to know not just the subject matter they teach but also the manner in which the subject matter can be changed by the application of technology” (P. Mishra & Koehler, 2006, p. 1028). On the other hand, “TPK is an understanding of how teaching and learning can change when particular technologies are used in particular ways. This includes knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies” (Koehler & Mishra, 2009, p. 65).
In addition to the TPACK contribution, Puente (2006) introduced the SAMR (Substitution, Augmentation, Modification, Redefinition) model, which aims to help teachers integrate technology into their teaching and learning process (Puentedura, 2006). The model was designed to help teachers think about how to get the best out of the technology from the enhancement of existing practices to the development and creation of new practices in practical ways. It also assists teachers to design, develop and integrate digital learning experiences that utilise technology to transform learning experiences in order to help students reach high levels of achievement and meet specified learning outcomes (Puentedura, 2011). The SAMR model describes the different levels of technology adoption and enhancement and the possibility of transformation in teaching and learning. The four levels of the SAMR model range from substitution at the lowest level to redefinition at the highest (Figure 2.2). The first two levels of the model are considered to describe enhancement of learning tasks, whereas levels three and four represent transformation.

![Figure 2.2. The four levels of the SAMR model (Puentedura, 2011)](image)

Regarding mathematics teaching, teachers’ knowledge, views, beliefs, attitudes and decisions about how to teach mathematics with technology play a crucial role in the
development of their TPACK (Bingimlas, 2009; Niess, van Zee, & Gillow-Wiles, 2011; Özgün-Koca, Meagher, & Edwards, 2010). Although the use of technology in mathematics teaching and learning has many advantages (Atweh & Goos, 2011; Niess et al., 2011), it has been argued that few teachers have been taught to teach their subject matter with technology and feel comfortable using technology in their teaching (Niess et al., 2009; Smerdon et al., 2000). There are many reasons for limited knowledge of technology integration by some teachers and several factors and barriers can influence a teacher’s integration of ICTs in the classroom (Balanskat et al., 2006; Bingimlas, 2009; DET, 2006; Jones, 2004; Pelgrum, 2001). These factors include: lack of teachers’ confidence, lack of teachers’ competence, resistance to change and negative attitudes, lack of time, lack of effective training, lack of accessibility to appropriate resources and lack of technical support (Balanskat et al., 2006; Bingimlas, 2009; DET, 2006; Jones, 2004; Pelgrum, 2001).

In Australia, many teachers have limited knowledge and skills to use technology and are not enthusiastic about the changes and integration of computer-based tools in to their teaching practices (DET, 2006; Newhouse, 2002). According to the Department of Education and Training’s Teacher ICT Skills Report (2006), in Western Australia, “82% of teachers are not regularly using ICT in the classroom. Of those teachers who are using ICT regularly (18%), most are doing so to improve computer skills and to find about ideas and information” (p. 6).

The next section of this chapter explains the place of mathematics and teaching mathematics in primary school classrooms.

2.2. Teaching mathematics in the primary school

Mathematics has a central position in primary school curricula (Anthony & Walshaw, 2009) and mathematical understanding influences decision making and increases opportunities for young people in their current and future private, social and civil lives. Unfortunately, today, as in the past, many students struggle with mathematics in the classroom and in their daily lives (Anthony & Walshaw, 2009; Offer & Bos, 2009). Due to these issues, there is an increased concern around the teaching of mathematics to young children (Clements,
Sarama, & DiBiase, 2004; Saracho & Spodek, 2009). Friedrich Froebel, Maria Montessori, and other pioneers in the education of young children raised awareness about the importance of mathematics teaching in the early years of school, and Piagetian and Vygotskian theories propose that young children should obtain an informal understanding of mathematics in the early stages of their lives. Piaget identified children’s early type of mathematics knowledge as logico-mathematical (Piaget & Inhelder, 1969), meaning that the young child’s brain constructs an understanding of the world around them, then creates a relationship between what they already know and what they discover in their environment (cognitive development). This learning is enhanced when adults guide their thinking by posing questions to scaffold the child’s discovering, wondering and comprehending (Vygotsky, 1978). These theories remain important underpinnings in the teaching and learning of mathematics for infants, preschoolers, and primary school children.

The increasing awareness of the importance of mathematics for society and for children’s own development has led to an increase in awareness of the importance of mathematics education for young children (Doig, McCrae, & Rowe, 2003; Saracho & Spodek, 2009). Hence, many countries around the world have developed pedagogical frameworks for the mathematics education of young children. Australia, along with other countries such as New Zealand, England, United State and Canada, has undertaken initiatives designed to improve the teaching and learning of mathematics among young children and to promote their mathematical thinking. In recent years, the mathematics education of young children has received increased attention among Australian researchers (Clarke, Cheeseman, & Clarke, 2006; Perry, Young-Loveridge, Dolckett, & Doig, 2012; Thomson, Rowe, Underwood, & Peck, 2005; Young-Loveridge, 2004). The Australian Association of Mathematics Teachers and Early Childhood Australia (AAMT/ECA, 2006) states that:

“The Australian Association of Mathematics Teachers and Early Childhood Australia believe that all children in their early childhood years are capable of accessing powerful mathematical ideas that are both relevant to their current lives and form a critical foundation for their future mathematical and other learning. Children should be given the opportunity to access these ideas through high quality child-centred activities in their homes, communities, prior-to-school settings and schools” (p. 2).
Paralleling these changes, there have been curriculum changes in Australia. Mathematics has a strong place in the Australian Curriculum. The Australian Curriculum: Mathematics (AC:M) is organised around the interaction of three content strands and four proficiency strands. The content strands are Number and Algebra, Measurement and Geometry, and Statistics and Probability that describes what is to be taught and learnt. In addition, there are four proficiency strands; namely, Understanding, Fluency, Problem Solving, and Reasoning. These involve the thinking and doing of mathematics and describe how content is explored or developed. The proficiency strands provide “the language to build in the developmental aspects of the learning of mathematics” (ACARA, n.d.) and have been incorporated into the content descriptions of the three content strands.

The Australian Curriculum: Mathematics aims to ensure that students:

- are confident, creative users and communicators of mathematics, able to investigate, represent and interpret situations in their personal and work lives and as active citizens;

- develop an increasingly sophisticated understanding of mathematical concepts and fluency with processes, and are able to pose and solve problems and reason in Number and Algebra, Measurement and Geometry, and Statistics and Probability;

- recognise connections between the areas of mathematics and other disciplines and appreciate mathematics as an accessible and enjoyable discipline to study;

(ACARA, n.d.)

Moreover, the rationale of the Australian Curriculum: Mathematics clearly declares that:

“The Australian Curriculum: Mathematics provides students with essential mathematical skills and knowledge in Number and Algebra, Measurement and Geometry, and Statistics and Probability. It develops the numeracy capabilities that all students need in their personal, work and civic life, and provides the fundamentals on which mathematical specialties and professional applications of mathematics are built” (ACARA, n.d.).

Therefore, the Australian Curriculum makes it clear that mathematics education has a
strong position in the curriculum, even in the early years of schooling. It also highlights that technologies should be embedded in all learning areas, including mathematics. Thus, they can no longer be viewed as optional tools. Learning mathematics through technology, especially multimedia learning, can give children access to powerful new ways to explore concepts at a depth that has not been possible through traditional ways of teaching. A multimedia approach can be a powerful tool for the visualisation and representation of mathematical concepts and can facilitate the learner’s abstract thinking. Using multimedia and computer-based tools can also allow multiple representations to be linked dynamically; for instance, changing a formula that can instantly change a graph (Milovanović, Takači, & Milajić, 2011) or showing a numeral and having multiple representations of the relevant number available in pictures, sounds and even animation.

2.3. Pedagogy in mathematics

‘Pedagogy’ refers to strategies of instruction, or a style of instruction used to promote development and learning (Epstein, 2007). Teachers can provide opportunities for students to learn and understand mathematics concepts in various ways. Many instructional strategies exist and several approaches may be utilised throughout any teaching and learning process, depending on a number of factors such as the level of students, goals, intent and objectives of the teacher, content, and environment including time, physical setting and resources (Petrina, 2007). Storytelling, fluency building strategies and problem solving are well known pedagogical approaches in mathematics education for young children.

Inclusion of children’s literature in the teaching and learning of mathematics is supported by a growing body of research in the field of mathematics education for young children (Goral & Gnadinger, 2006; Haven, 2000; Robin, 2008; Thiessen, 2004; Ward, 2005; Wilburne, Keat, & Napoli, 2011; Zazkis & Liljedahl, 2009). Haven (2000), stated: “Telling a story creates more vivid, powerful and memorable images in a listener’s mind than does any other means of delivery of the same material” (p. xvii). His study indicated that storytelling in the classroom can be a powerful and effective way of learning and can motivate students to be active learners, as they take an active part in telling and writing stories.
“Factual and conceptual information is learnt faster and better, and will be remembered longer, recalled more readily, and applied more accurately when that information is delivered as a well-told story” (Haven, 2000, p. 75).

Using children’s literature (storytelling) to teach mathematics has been proven to be an effective method and can motivate learners to think, to imagine, and to learn (Elia, van den Heuvel Panhuizen, & Georgiou, 2010; Thiessen, 2004; Tucker, Boggan, & Harper, 2010; Zazkis & Liljedahl, 2009) because it enables children to enter into the storybook world and become emotionally involved with the story through pretending and imagining and learning mathematics in the context that is meaningful for them (Wilburne et al., 2011). Storytelling can create powerful and memorable images in a learner’s mind (Zazkis & Liljedahl, 2009) and help them link mathematics concepts to their existing knowledge and understandings about the world.

Mathematics is part of everyday life, and children’s literature can be used as a bridge for children to connect the abstract and symbolic language of mathematics to their own world through engaging in meaningful conversations (Wilburne et al., 2011). The US National Council for the Teachers of Mathematics (NCTM, 2000) considers communication as an essential component of learning mathematics, and the mathematical achievement of children is highly correlated with their ability to use language to communicate their maths ideas (Tucker et al., 2010; Ward, 2005). Hence, using literature can enable children to communicate mathematically through listening, reading, writing and talking about mathematics ideas, leading to increased depth in their understanding of difficult concepts as well as their ability to talk about and represent the ideas.

Moreover, it has been argued that posing mathematics problems through storytelling can increase children’s use of vocabulary and language and enable them to connect the language of the story to the language of mathematics (Wilburne et al., 2011). Using language to solve a mathematics problem helps children to makes more sense of mathematics and thinks about what they doing. “By posing a mathematics problem through a character in a story, the children were excited to explain how they solved the problem to the characters (Wilburne et al., 2011, p. 16).
Storytelling is a practical and powerful teaching tool (Tsou, Wang, & Tzeng, 2006; Wilburne et al., 2011), which can provide opportunities for teachers to make mathematics concepts realistic and meaningful to students. It has been claimed that, when carefully selected and meaningfully shared, mathematics concept storybooks provide a rich and engaging context for promoting children’s mathematical explorations, reasoning and critical thinking throughout early grades (Goral & Gnadinger, 2006; Ward, 2005; Wilburne et al., 2011; Zazkis & Liljedahl, 2009). Wilburne et al. (2011) supported this by saying that: “By integrating storybooks with mathematics, early childhood teachers can plan a comprehensive approach to teaching mathematics, with lessons aligned to state and national standards to enhance students’ mathematical abilities in ways that are developmentally, culturally and individually appropriate” (p. 2). To provide opportunities for children to make connections between the mathematics concepts in storybooks and the mathematics in their own world, teachers can use a variety of strategies, including: explicit teaching and scaffolding instruction, fluency building (skill building) and problem solving.

Explicit teaching involves directing students’ attention toward specific learning through a sequence of supports, involving: first, setting a purpose for learning (telling students what they are going to learn) and based on teacher’s understanding of what students already know; telling students what to do, then showing them how to do it; and, finally, guiding their hands-on application of the new learning (Boyles, 2001).

Explicit teacher modelling can be combined with additional instructional strategies, such as Scaffolded Instruction. Scaffolded instruction is based on the idea that at the beginning of learning, students need a great deal of support from teachers. Teachers provide students the opportunity to demonstrate what they have learned and receive immediate feedback. Instruction moves gradually from extensive teacher input and little student responsibility to total student responsibility and minimal teacher involvement at the conclusion of the teaching and learning process (Boyles, 2001; Cooper, 1993). If students are unable to achieve independence, the teacher brings the help system back to assist students experience success until they are able to achieve independence (Cooper, 1993).
‘Fluency’ is the ability to express something effortlessly, clearly and with automaticity (ACARA, n.d.). Mathematics fluency can be described as the ability to compute maths facts (for example, addition, subtraction, multiplication and division) and problems quickly and with confidence (Mercer & Miller, 1992; Tait-McCutcheon, Drake, & Sherley, 2011). According to ACARA, students are considered to be fluent when they can calculate answers efficiently and confidently, find various answers, recall definitions and (for older children) manipulate equations and terms to find answers (ACARA, n.d.). The recall of basic facts is recognised as a vital goal of mathematics education in primary schools since the prompt recall of mathematics facts can ensure that students have the cognitive capacity to attend to the more complex activities of problem solving and higher-order processing (Tait-McCutcheon et al., 2011).

Fluency building or skill building is an instructional strategy that “promotes the acquisition of knowledge or skill through repetitive practice” (Adams, 2007, p. 72) in order to learn or become proficient. Skill building involves repetition of specific skill, such as addition and subtraction, or the practising of mathematics facts (for example, multiplication and division) to express something effortlessly, clearly and with automaticity (fluency). To develop or maintain specific skills, first the type of skill being developed needs to be identified and then appropriate strategies need to be used for practising small tasks (building blocks) of certain subjects through practice in order to learn or become proficient.

‘Problem solving’ can be described as a process of knowing a problem, considering all the details of the problem and working through the details of the problem to reach a solution and is recognised as a very important task in mathematics education (Lazakidou & Retalis, 2010). Elshout (1987) identified problem solving as a cognitive function that requires the problem solver to recall and process the relevant information. Although the construct of problem solving has no commonly accepted definition in mathematics education, it undoubtedly involves higher order thinking, which depends to a large extent on the fluency of lower level learning.

Reflective Problem Solving is one of the major types of problem solving, where students define the problem, analyse the problem, establish the criteria for evaluating solutions, propose solutions and take action (Wilburne et al., 2011). The process of reflective problem
solving is more than the simple recall of facts or information retrieval (Tay, Lim, Lim, & Koh, 2012; Wilburne et al., 2011). Rather, it is a function of cognitive strategies that requires the problem solver to recall and process the relevant information and knowledge during novel problem solving processes. It involves higher order thinking, where learners are required to recognise, understand and analyse a problem. Then, all of the components need to be evaluated and incorporated to create a new form or representation. Students can work individually, in pairs or in small groups to analyse and find solutions to a mathematics problem without teachers’ assistance or instruction.

The study being reported here draws on a cognitivist approach to learning, which focuses on mental processes and how learners attend to, manipulate and remember information during learning. Cognitive education in the teaching and learning process encourages learners to think and analyse a particular topic in gradually more complex ways (Krause, Bochner, & Duchesne, 2006). In 1956, Bloom described a hierarchical model for cognitive learning objectives, ranging from lower levels of learning (i.e. knowing and understanding) to higher levels of thinking, which require a more sophisticated way of evaluating and analysing content (Bloom, 1956). In 2001, Anderson and a team of cognitive psychologists revisited Bloom’s model and made some changes to the terminology and the structure of the existing taxonomy (Anderson et al., 2001). These two versions of the taxonomy are often referred to as Bloom’s taxonomy (Bloom, 1956) and the revised Bloom’s taxonomy (Anderson, et al., 2001). The Bloom/Anderson taxonomy represents the learning process in six categories:

- **Remembering**: This is about retrieving, recalling, or recognising knowledge from memory. Remembering is necessary when memory is used to produce definitions, facts, or lists, or recite or retrieve material.

- **Understanding**: This is about constructing meaning from different types of functions, be they written or graphic messages activities like interpreting, exemplifying, classifying, summarising, inferring, comparing, and explaining.

- **Applying**: This is about carrying out or using a procedure through executing, or implementing and applying related information referring to situations where learned material is used through products like models, presentations, interviews or simulations.
• **Analysing:** This is about breaking material or concepts into parts, determining how the parts relate or interrelate to one another or to an overall structure or purpose. Mental actions included in this function are differentiating, organizing, and attributing, as well as being able to distinguish between the components or parts. When a person is analysing, he/she can illustrate this mental function by creating spreadsheets, surveys, charts, or diagrams, or graphic representations.

• **Evaluating:** This is about making judgments based on criteria and standards through checking and critiquing. Critiques, recommendations, and reports are some of the products that can be created to demonstrate the processes of evaluation. In the newer taxonomy, evaluation comes before creating, as it is often a necessary part of the precursory behaviour before creating something.

• **Creating:** This is about putting elements together to form a coherent or functional whole; reorganising elements into a new pattern or structure through generating, planning, or producing. Creating requires users to put parts together in a new way or synthesise parts into something new and different in a new form or product. This process is the most difficult mental function in the new taxonomy.

(Anderson et al., 2001)

As mentioned above, teaching mathematics through storytelling is a powerful strategy that can engage children in mathematics discussion before, during and after reading storybooks. The teacher can pose questions that stimulate children's thinking about new vocabulary, concepts, facts, possibilities, reasoning, probabilities, problems and more (Wilburne et al., 2011). Wilburne et al. (2011), proposed three approaches for teachers to make mathematical connections through storytelling that are cognitively stimulating, authentic and exciting for young learners. The first approach is to read through the book and find opportunities to pose mathematics questions. Through this approach, known as Posing High Level Thinking Questions, teachers can use a list of verbs associated with higher-level thinking and the Bloom/Anderson taxonomy (Anderson et al., 2001) as a guide to pose questions that require children to use their critical thinking and problem solving skills. In this approach, teachers can also create open-ended problems to encourage children to think and apply various strategies for solving problems.
The second approach suggested by Wilburne et al. (2011) involves using the storybook elements to create an interesting mathematics lesson that can be discussed through the use of different parts of a storybook and related mathematical concepts. In this approach, teachers can use the plot, theme, setting, timeframe, characters, objects and illustrations in the story to identify situations in which mathematics problems may exist, or explain mathematics concepts and pose questions.

The curriculum standards approach is the third approach, which involves teachers selecting a mathematics standard (learning objective) for a grade level and reading a storybook, looking for opportunities to relate the story to the standard or connect the standard to the various elements of the story. For example, teachers can read a storybook aloud so that children can become familiar with the context of the story, as well as the characters, theme and plot. Then, by identifying and having a mathematics standard in mind, teachers can create a situation that the character is facing a problem and children can help to solve this problem.

Moreover, in the teaching of mathematics, research studies have shown that multiple representations have an important role in developing children’s understandings of mathematics concepts (Carpenter, Fennema, Franke, Levi, & Empson, 1999; Gray, Pitta, & Tall, 1997; Harries & Barmby, 2007; S. Mishra & Sharma, 2005; Thompson, 1999) and can serve as significant teaching aids for learners, because each representation contains important information for learners. Engaging in multiple representations can enable learners to better understand, develop, and communicate different mathematical attributes of the same object or operation, along with connections between them (Carpenter et al., 1999; Harries & Barmby, 2007; S. Mishra & Sharma, 2005). The National Council of Teachers of Mathematics Standards (NCTM, 1989) strongly supports the use of multiple representations in mathematics education:

“Different representations of problems serve as different lenses through which students interpret the problems and the solutions. If students are to become mathematically powerful, they must be flexible enough to approach situations in a variety of ways and recognize the relationships among different points of view” (p. 84).
There is a variety of ways in which multiple representations can be used to convey mathematics concepts, and computer-based technology has been identified as being capable of providing this (Goldin & Shteingold, 2001; Milovanović et al., 2011). The use of multimedia and computer-based tools can facilitate the learner’s abstract thinking and allow multiple representations to be linked dynamically between concrete and symbolic representations. The current study used these two approaches (storytelling and multiple representations) in teaching mathematics as a basis for designing new interactive multimedia software for teaching and learning mathematics in the primary classroom.

2.4. Existing computer-based mathematics applications and their pedagogical limitations

It has long been claimed that the use of computers can increase the mathematical achievement of children in pre-school and primary grades, and as already noted, the largest gains so far appear to have been through the use of mathematical training and practice software (Adams, 2007; Clements, 1987; Clements & Nastasi, 1992; Yelland, 2001). In recent years, the teaching and learning of mathematics through computer-based education software has been growing rapidly. However, although several educational software and applications have been developed, many of them have not been successfully used in the school setting. Evidence suggests that much educational software that is commercially produced is not widely accepted by educators, policy makers and researchers (Kingsley & Boone, 2008). Studies have shown that software is rarely designed with an appropriate pedagogical framework in mind (Laurillard, 2009; Mumtaz, 2000; Patten, Arnedillo Sánchez, & Tangney, 2006) and that it also has inadequate consideration for the teaching contexts in which it is supposed to be used (Hinostroza & Mellar, 2001).

It has been asserted (Laurillard, 2009) that to get the best outcomes from technology, any teaching resource (such as software) needs to be designed with the requirements of teaching and learning as the starting point. However, few educational applications are based on the requirements of education, in terms of both learners’ and teachers’ needs. In the process of educational software development, communication between software developers and end users, and the process of analysing and understanding users’ requirements and needs, are
crucial. However, developers often communicate with computers for much of their time, thus having less time to interact with human beings to find out their requirements (Carbonara, 2005) or understand the environment in which the software will to be used. “Developers are often unable to understand the user world” (Carbonara, 2005, p. 276). Thus, for most developers, understanding the user domain knowledge or users’ language (in this case, teachers and learners) and interpreting that original information (users’ requirements) into a software application is an area of challenge.

“The development of models or methods for the construction and use of educational software is, as a rule, either oriented toward the rationale of software engineering, or, consequently lacking in teaching parity, refers to the teaching characteristics of the software and is thus often fragmentary” (S. Mishra & Sharma, 2005, p. 117).

Inappropriate design of multimedia in terms of educational content (such as using extraneous audio and graphics) and an inadequate ability to provide an effective learning environment are other problems associated with educational software (Sim, MacFarlane, & Horton, 2005). It has been argued that many applications are largely driven by financial, logistical and technical agendas and not pedagogical considerations, and they mainly concentrate on the software itself and not the educational theory underpinning it (Morehead & LaBeau, 2005; Patten et al., 2006). Further to the above issues, it has been pointed out that there is often a disconnection between theory for designing educational applications and theory relating to the application of technology in classrooms (Offer & Bos, 2009). Frequently, software developers do not consider any educational theory in designing computer-based educational applications, or they disregard how theoretical principles influence a classroom environment. Thus, in many cases, the methods for application in the classroom are inconsistent and the strategies of integration and use of the application by teachers are not intended by the developers (Hickey & McCaslin, 2001; Offer & Bos, 2009). Moreover, lack of alignment between technology, curriculum and pedagogy in many existing mathematics computer-based application is one of the main cause of rejection of using and integrating these technology in teaching and learning process (Mumtaz, 2000; Robin, 2008; Yelland, 2001).

To add to the above issues, the provision of feedback to children has often been a weak
link in educational software, offering little beside whether the child’s response is correct or incorrect (Gadanidis, 2004). Immediate and appropriate feedback on individual responses is one of the main potential advantages of computer-based education (Mason & Bruning, 2001), and can help learners and their teachers to identify errors and become aware of misconceptions and areas that need to be consolidated. Halladay and Neumann (2012), supported this by saying: “Monitoring problem solving [by teachers], like monitoring reading comprehension, can help students identify mistakes and repair misunderstandings” (p. 472). Therefore, explaining the reasons for incorrect answers and providing students with appropriate methods of solving problems and arriving at correct answers and processes are more effective and motivational (Mason & Bruning, 2001).

The lack of provision for collaborative learning is another shortcoming of many existing educational applications, since they are often designed for the individual learner and are underpinned by behaviourist principles, leading to repetition and individualised drill and practice. Whilst this may have a place, collaborative learning can enable learners to share, exchange and discuss their ideas. It also enables learners to learn from their peers and build on their skills (Laurillard, 2009; Pifarré & Staarman, 2011). For example, to tackle a mathematics problem in a collaborative way, learners have a chance to define their own approach, articulate and examine their thinking, and also the opportunity to learn from their peers. In the digital age, new technologies, especially handheld devices, are creating new opportunities for supporting collaborative learning; however, digital tools of this kind are rarely developed with the learners’ and teachers’ needs in mind (Laurillard, 2009).

2.5. Statement of the problem

It is clear from this literature review that computer-based technology, especially interactive multimedia software, has the potential to provide successful teaching and learning experiences for both teachers and learners. However, it is argued that not many educational applications fit well in Australian primary school settings to facilitate mathematics learning in a manner that is considered to be pedagogically appropriate by teachers.

In the kindergarten (also known as Foundation Year in the new Australian Curriculum), pre-primary and primary classroom, which in Australia covers K to Year 6 (children aged 5 to
11), there are many opportunities for computer-based technology to enhance the teaching of curriculum areas such as English and Mathematics (Lim & Oakley, 2013). But, many studies and computer-based applications that are currently used in Australia originate from the USA (Eng, 2005; Yelland, 2001), although in recent years more have been coming from the UK or other countries such as India. Subsequently, educational packages are mainly based on the curricula of these countries and their teaching philosophies and methods. Thus, in many cases, sourcing computer-based technology and applications to facilitate learning in a pedagogically acceptable manner has become an area of challenge for Australian schools. Therefore, there is a great need for Australian-based quality software to address many issues that discussed through the literature and to cover the needs of Australian teachers and students.

2.6. Chapter conclusion

This chapter firstly presented and summarised the relevant literature related to role of interactive technology, particularly interactive multimedia technology in teaching and learning. Second, it defined multimedia and the potential impact of interactive multimedia software applications on education, particularly in mathematics teaching and learning. Cognitive load and Clark and Mayer’s (2011) design principles for designing effective educational multimedia application were also explained.

This chapter also discussed the place of mathematics in the Australian Curriculum and mathematics teaching strategies and pedagogies in the primary school. Using children’s literature as a pedagogical tool for teaching and learning mathematics in the early primary years, as well as teachers’ technological knowledge and teacher beliefs on integrating technology in their mathematics classroom were given particular emphasis. The Bloom/Anderson taxonomy, which draws on a cognitivist approach to learning, was also explained.

Furthermore, this chapter reported a number of issues relating to existing computer-based mathematics applications and their pedagogical limitations. Through this review, a number of issues have been identified about the design of computer-based applications in Australian educational contexts. The next chapter explains more fully the research design, a new conceptual framework, and the process of the research investigation.
This chapter presents the research approach, conceptual framework and instructional system design model employed in this study. The research approach is discussed in terms of the philosophical assumptions the researcher brings to the study and the research design. The conceptual framework, which is based on a cognitive learning theory, specifically the Bloom/Anderson taxonomy, is discussed and justified. Instructional System Design in general and a systematic instructional design model, which was used in this study for progressing towards the educational objectives, are also discussed. The process of investigation, the research methods used for data collection, analysis and interpretation, as well as a description of the steps taken to maximise the trustworthiness and rigour of the research, are described. In the final part of the chapter, the ethical issues considered in the realisation of this study are discussed.

3.1. Research approach

This study applied a mixed method approach to address the research questions following the research design method of Creswell’s (2013) Framework for Design. Mixed method research is an approach to inquiry that involves the collection, analysis, and integration of
both quantitative and qualitative data in a single study to understand a research problem (Creswell, 2013, p. 4; Tashakkori & Teddlie, 2010).

According to Creswell (2013, p. 5), a research approach is the plan or proposal to conduct research, and involves the intersection of philosophy, research designs, and specific methods of data collection, analysis and interpretation. Creswell’s framework identifies and explains the interaction of the three components in the research approach, which are: (a) the basic philosophical assumption/worldview that a researcher brings to a study; (b) overall strategies of inquiry used in the research, which are related to the worldview, and; (c) the specific research methods employed to translate the approach to practice. This study applied this broad framework as a guideline for the research design deemed to be most appropriate for answering the research questions.

The philosophical or world view component relates to ‘the world and the nature of research that a researcher brings to study’ (Creswell, 2013, p. 6). In this study, a pragmatic worldview was chosen for its emphasis on ‘situations and consequences’ and on contextualised solutions ‘that work’ (Creswell 2009, p. 10). Also, concentrating on the research problem and using available approaches to understand the problem and solutions to the problem, instead of focusing on methods, are outlined as essential criteria of pragmatic approaches (Creswell, 2013; Tashakkori & Teddlie, 2010). Pragmatism as a philosophical underpinning for mixed methods is, therefore, in line with the nature of the study reported here through focusing on the research problem (as outlined in Chapter 2), solutions to the problem and the gathering of experience and knowledge of what does and does not work in the natural setting, and making decisions based on practical consequences. Moreover, pragmatism is argued to be the most appropriate approach to mixed method studies (Creswell, 2013; Johnson, Onwuegbuzie, & Turner, 2007; Morgan, 2007; Tashakkori & Teddlie, 2010), as this view is not dedicated to any one system of philosophy and reality. This applies to mixed methods research, which draws from both qualitative and quantitative assumptions and integrates two forms of data (Creswell, 2013) in response to research questions.

This study aimed to investigate the use of educational multimedia software (tools) in teaching and learning mathematics in the primary years of school (K-Year 4). A Convergent Parallel
Mixed Method (Creswell, 2013) approach was considered to be the most appropriate choice for both phases of the study because of its strength in drawing together qualitative and quantitative research methods and minimising the limitations of both approaches in answering research questions. A Convergent Parallel Mixed Method design is a “type of design in which the qualitative and quantitative data are collected in parallel, analysed separately and then merged” (Creswell, 2013, p. 133) (Figure 3.1). The rationale for this approach is that the quantitative data and their subsequent analysis provide a general understanding of the research problem. The qualitative data and their analysis refine and explain those statistical results by exploring participants’ views in more depth (Creswell, 2013).

The convergent parallel mixed method is also an effective approach in developing a more complete understanding of the needs and impact of intervention programs (Creswell, 2013; Tashakkori & Teddlie, 2010), to be used in real world contexts involving the gathering of data in natural settings, which fits well with the proposed research project. Furthermore, the method provides much more detailed information through data collection from multiple methods and sources of evidence (i.e. questionnaires, interviews, documents review and observations). The detailed view of participants on the implementation of the tools in classrooms qualitatively, along with scoring the tools quantitatively, provides multiple sources of data to allow the evaluation of tools, processes and programs.

The complexity and novelty of this project led the study to include an advanced strategy
to cover criteria of both educational and technological objectives. Therefore, this study’s program implementation and evaluation were conducted in two phases, where the second phase (Phase 2) was built on the results and experiences of the first phase (Phase 1). In Phase 1, mixed method was used throughout the implementation of the program, followed by concurrent qualitative and quantitative data collection. Different strategies and activities (such as systematic observation and ongoing formative evaluation) were also used to identify strengths and weaknesses within the design context and to critically evaluate the tools when they were implemented in real world settings (classrooms).

The main objectives of Phase 1 were to examine and investigate the practicality of the proposed conceptual framework (section 3.2) as a basis for designing educational multimedia software. The usefulness of the selected instructional system design model (section 3.3) and interactive multimedia software development model (Chapter 4) were other important reasons for conducting this phase. Furthermore, in this phase, the data collection methods and all designed instruments (such as questionnaires, interviews and systematic observations) were trialled and refined. Based on the findings, detailed information of what did and did not ‘work’ and insights gained in Phase 1, led to adjustments and refinements for Phase 2.

Phase 2 of the study was conducted in early 2013 for three school terms (three of the usual four school terms). The convergent parallel approach was applied to this phase with a focus on the overall research objectives, which resulted in a final evaluation of the tools and understanding of the research problem and response to the research questions. Figure 3.2 illustrates the main phases of the study’s research design.

![Figure 3.2. The study’s research design based on mixed methods approaches (Creswell, 2013)](image)

The conceptual (educational) framework of the study is discussed in the next section.
3.2. Conceptual framework

The Bloom/Anderson taxonomy is a useful learning model and is widely used as a planning tool in educational settings (Krause, Bochner & Duchesne, 2006; Thompson, Luxton-Reilly, Whalley, Hu, & Robbins, 2008), and has been applied in higher education domains such as engineering, structuring assessments and computer science for course design and evaluation (Thompson, et al., 2008). However, the approach has seldom been used for designing computer-based educational applications for schools. In the study being discussed here, the Bloom/Anderson taxonomy was used to inform the design of a mathematics educational framework, which in turn underpinned the design and development of a computer-based application (Educational Interactive Multimedia Software) to facilitate the teaching and learning of mathematics concepts in primary school classrooms.

Figure 3.3 illustrates the Bloom/Anderson taxonomy, which consists of six major categories including Remembering, Understanding, Applying, Analysing, Evaluating, and Creating (Anderson, et al., 2001). The first three categories, namely Remembering, Understanding and Applying, require a good deal of involvement and scaffolding from teachers, and focus on knowledge, comprehension and application. The other three categories are more sophisticated and involve higher order thinking by learners. These elements emphasise Analysing, Evaluating, and Creating.

![Figure 3.3. Categories in the cognitive domain of Bloom/Anderson Taxonomy (Anderson, et al., 2001) Source: http://www.educationworld.com/a_curr/mathchat/mathchat026.shtml](http://www.educationworld.com/a_curr/mathchat/mathchat026.shtml)
This study proposed a new framework for designing mathematics software, which captured all elements of the Bloom/Anderson taxonomy (Figure 3.4). As shown in the literature review, storytelling, skill building (fluency building) and problem solving are three effective approaches to mathematics education for young children, and these three approaches are at the core of the proposed framework. As is shown in Figure 3.4, storytelling is the first level of the framework (lower section), where the whole class can be engaged. Here, there is substantial teacher involvement (scaffolding) to focus children’s attention on the story and the embedded mathematical concepts, and to build comprehension. The storytelling method can assist learners with reference to the recall of facts, terms and concepts, and can encourage them to imagine and sequence story scenes (Krause, et al., 2006; Tucker, et al., 2010). This ties in with the first category (Remember) of the Bloom/Anderson model. Also, storytelling can assist teachers in teaching comprehension of a subject through explaining the scenes, retelling the story, asking ‘why’ and ‘how’ questions, and having children describe scenes and characters (which should contain maths concepts) in their own words (Krause, et al., 2006; Tucker, et al., 2010) (The “Understand” category of Bloom/Anderson model). Therefore, storytelling covers both “Remembering” and “Understanding” in the Bloom/Anderson model.

The middle section of the framework focuses on the skill building of individual students through the use of knowledge and understanding already gained through the first level. Skill building (fluency building) can be described as a way of learning by developing a capacity to retrieve basic facts from memory quickly and effortlessly (with automaticity). This can be achieved through practising, repeating and accomplishing. This aligns with the “Apply” category of the Bloom/Anderson model.

Problem solving is a “higher-order cognitive process” (Goldstein & Levin, 1987) that entails the ability to recognise, understand and analyse a problem. Finally, all of the components need to be evaluated and incorporated to create a new form or representation. This can be related to the last three categories (“Analyse”, “Evaluate” and “Create”) of the Bloom/Anderson model, which require a higher order of thinking by learners (Anderson, et al., 2001). As presented in Figure 3.4, this is the upper level of the proposed framework, where students can work individually or in pairs or small groups to analyse and find solutions to
maths problems. Learners have the opportunity to move back and forth between these three levels of the framework, as required.

![Proposed educational framework](image)

Figure 3.4. Proposed educational framework

The conceptual ties between the Bloom/Anderson model and the proposed framework provide a strong basis for designing a computer-based mathematics educational application (Figure 3.5).

![Conceptual ties between Bloom/Anderson taxonomy and the proposed framework](image)

Figure 3.5. The conceptual ties between the Bloom/Anderson taxonomy and the proposed framework
3.3. Instructional system design

One of the main aims of the study was the design and development of a dynamic computer-based application to facilitate the teaching and learning of mathematics concepts in primary classrooms. To create such a dynamic system, a systematic design process was required to be applied towards the educational objectives. This systematic approach, known as Instructional Systems Design (ISD) or Instructional design (ID), provided: a step-by-step process for the analysis of the teachers’ and learners’ needs; defining the goal of instruction; the design and development of materials and tools to assist in the transition; and the evaluation of the effectiveness of the educational software strategy (Briggs, 1991; McArdle, 1991; Reigeluth, 1983).

“Instructional Design simply means using a systematic process to understand a human performance problem, figuring out what to do about it and then doing something about it” (McArdle, 1991, p. 3).

Briggs, 1997 also stated: “Instructional Design is the entire process of analysis of learning needs and goals and the development of a delivery system to meet the needs” (Briggs, 1997, p. xx).

Therefore, instructional system design is a pedagogic or teaching device that makes instruction as well as the instructional material more engaging, effective and efficient to learners. Learning theories also play an important role in the design of instructional materials (Reigeluth, 1983) as there is a logical development from learning to instruction. “Instructional design optimizes learning outcomes while learning theories are the backbone of any instructional design” (Reddi & Mishra, 2003, p. 28).

Instructional system design is the manifestation of learning theories (Reddi & Mishra, 2003), and its main goal is to optimise learning and learning environments by using the known theories of learning. As explained in the literature review, behaviourism, cognitivist and constructivism are all prominent theories of learning. All three learning theories can be incorporated into an instructional system individually or in combination with creativity in identifying and solving instructional problems (S. Mishra & Sharma, 2005; Reddi & Mishra, 2003).
The cognitive learning theory underpinning the Bloom/Anderson taxonomy (which is the basis of the proposed conceptual framework) influenced the instructional system design process of this project. Various educational objectives and techniques of the cognitive learning theory, such as breaking information into small parts, memorising content and practising, storing and retrieving information were incorporated to the instructional design process. For example, the inclusion of pictures for giving visual information about a learning subject will affect learning cognitive tasks as well as motor skills (Gagné, Wager, Golas, Keller, & Russell, 2005; S. Mishra & Sharma, 2005).

The instructional system design used in this study (Figure 3.6) incorporates the cognitive learning theory of the Bloom/Anderson taxonomy to shape and define computer-based instructional materials for assisting in teaching and learning mathematics in primary school. This will be explained in detail in Chapter 5.

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**Figure 3.6. Instructional system design components of My Maths Story applications**

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The composition of the conceptual (educational) framework and instructional system design components of My Maths Story interactive multimedia software application.

- **Source**
  - Multimedia elements
    - Text, image, animation, audio and video

- **Learning Theory**
  - Cognitivism

- **Pedagogies in mathematics teaching**
  - Using children’s literature and multiple representations

- **Content**
  - Interactive Storybook software
  - Student Activity software
  - Group Projects software
  - Problem solving-analysis, evaluate and create a maths problem

- **The educational framework**
  - Introduction, objective (remember and understand the maths concept)
  - Various maths concepts at different levels
  - Fluency (Skill) building
    - Easy
    - Moderate
    - Difficult

- **Interactive Storybook software**
  - Fluency building

- **Student Activity software**
  - Storytelling

- **Group Projects software**
  - Problem solving

- **Bloom/Anderson taxonomy**
  - Remembering
  - Understanding
  - Applying
  - Analysing
  - Evaluating
  - Creating
3.3.1. Instructional design models

There are various instructional design models and methods (S. Mishra & Sharma, 2005). Most instructional design models have systematic and similar components, but can vary greatly in the specific number of phases (Briggs, 1997; Dick & Carey, 1996; Merrill, 1994). Seels and Glasgow (1998) identified five common components of instructional design and developed the general ADDIE model. ADDIE is an acronym for (1) analyse, (2) design, (3) develop, (4) implement, and (5) evaluate. The ADDIE model is a systematic instructional design model, which represents a dynamic and flexible guideline for building effective training and supporting tools (Gagné et al., 2005).

“The ADDIE model has become a frequently referenced generic model of the ISD process. Its stages represent the major steps in systematic problem solving models which begin with identification of the problem and its causes (analysis), proposing a solution (design) preparing the solution (development), trying it out (implementation), and determining whether the solution was successful (evaluation)” (Gagné et al., 2005, p. 38).

This study used the ADDIE model of instructional system design as an organising framework for the processes of designing, developing and evaluating the multimedia educational applications. Clearly defined stages of the model follow a logical order intended to cover all critical elements of educational objectives. The model is iterative, which allows the cycle of analysis-design-development-implementation-evaluation to be repeated a number of times while instructional materials are being created. Furthermore, the ADDIE model is empirical, so data gathering is built into the process and decisions are made on the basis of data (Gagné et al., 2005). In addition, in the ADDIE instructional design model, the designer is constantly aware of the interdependence of the elements of the total instructional system (learners, teachers, materials, environments).

Because of all the above features and the capacity of the model to allow revision and ongoing feedback throughout all phases and make appropriate changes to the educational system during different stages of process, the ADDIE model was selected as an appropriate ISD model for the purposes of this study. Detailed considerations within each step of the
model provided a concrete framework to accomplish the complex development process to target particular educational objectives.

Figure 3.7 illustrates the major components of the ADDIE model. The solid lines indicate that the process flows from analysis to evaluation, and the dotted lines indicate feedback pathways.

3.3.2. ADDIE model process

3.3.2.1. Analysis

The analysis phase is the first and most crucial phase of the ADDIE instructional design model and all subsequent work is based on its outcomes. First, a needs analysis is conducted to determine the needs and requirements of the users. Then, the instructional problem is identified along with the establishment of instructional goals and objectives. Other tasks in this stage include: analysis of target users characteristics (in this case, teachers and learners), analysis of subject matter and design, pedagogical objectives, analysis of learning objectives, analysis of the learning environment and the review of existing applications.

The effective use of educational software in teaching and learning processes depends on balancing the software’s potential with the users’ needs and educational requirements (Boon
Shiong et al., 2008; Peterson, 2003). Thus, in the analysis phase, all of above prime factors should be considered to meet the teachers’ and learners’ needs through the provision of necessary tools and techniques in the instructional materials (in this case, educational interactive multimedia software).

The outcome of the analysis phase provides important information to support decisions during the subsequent design stages.

3.3.2.2. Design

The design phase is a process of planning for the construction of instructional materials based on the information or data from the analysis phase. This involves several key factors, including establishing specific objectives and specifying learning activities as well as selecting the media and methods that will be most effective in the delivery of the objectives (Sriram, 2011). Identifying or creating the subject content and developing a pedagogical strategy are vital components of this phase. Moreover, breaking the units down into lessons and learning activities, and clarifying teachers’ and learners’ contributions during the instructional period are other main elements that need to be addressed in the design phase.

Conducting a formative evaluation is highly recommended (Seels & Glasgow, 1998) as it provides an early opportunity for feedback concerning the subject content, functionality, feasibility, and appearance of instructional tools and strategies.

The results of this phase produce a set of specifications or plans for the developers to follow in producing the instructional tools.

3.3.2.3. Development

The development phase is where the results from the previous two phases are used to construct a product for the delivery or teaching of the content. This phase is a transitional stage that transforms the planning of instruction materials to a production mode to be used in the teaching and learning environment. Gagné (2005), declared this stage as a “challenging stage in instructional design because it can be approached from several directions depending on the relationships among the instructional objectives, degree of
detail in the design documents that provide input to development, the characteristics and appropriateness of new or existing materials, and the delivery system” (p. 31).

Since the instructional tools developed for the purpose of this study are in the form of educational interactive multimedia software, this stage includes details of the software development process. The detail of the software development process is covered in Chapter 4.

Furthermore, it is necessary to conduct formative evaluation during the development phase to assess the product features and to improve the quality standards of the software tools before implementation (Gagné et al., 2005). For this purpose, in this study, after the development of the tools and before implementation in schools, a substantial formative evaluation was conducted. The tools were presented to pre-service teachers and early primary mathematics educators (mathematics education professors) at a university in Western Australian. Each pre-service teacher and mathematics educator accessed different parts of the tools for testing and evaluation. Through this process, pre-service teachers’ and educators’ comments and suggestions were collected through questionnaires, and then analysed in order to inform improvements to the tools. The detailed results and analysis of this formative evaluation is reported in Chapters 5 and 6.

3.3.2.4. Implementation

The implementation phase of the ADDIE model addresses the execution of instructional materials and programs in to a real world environment. Implementation involves launching the developed educational tools and investigating their value in facilitating teaching and learning. Training the target users (in this case, teachers) and providing them with the support they need to integrate the new tools in their teaching process is one of the main tasks in the implementation phase. In this study, this training or professional development involved informing participant teachers with the goals and objectives of the computer program, introducing them to different features of the application, and how to link the tools to the curriculum. It also involved demonstrating how to use the tools in the teaching and learning process.

To address users’ technological and pedagogical questions or difficulties, ongoing
support during the implementation phase is required. Moreover, it is important to assure all components of the educational tools are functional throughout this stage (Gagné et al., 2005).

In this study, during the implementation phase of ADDIE, data collection occurred, such as ongoing observations in classrooms (see section 3.4.4, data collection tools). Other data collection strategies are employed towards the end of the implementation period (in this case, towards the end of the trial period in schools). Strategies include semi-structured interviews and questionnaires (see section 3.4.4 of this chapter).

3.3.2.5. Evaluation

The evaluation phase is the final and an essential component of the ADDIE model process, and consists of two parts, formative and summative. Formative evaluation occurs in each stage of the ADDIE process while the instructional materials are still being created. The purpose of formative evaluation is to collect information and feedback from target audience as the project is developed. Throughout this process, feedback is gathered from several types of stakeholders such as users (teachers and students), educators, content experts and technology experts. Formative evaluation provides guidance on how to improve instructional materials or the procedures by which they are designed and developed (Gagné et al., 2005; Peterson, 2003).

On other hand, the summative evaluation activities occur after new tools are fully launched through providing users with opportunities for giving feedback. The results from evaluation leads to decisions about the worth and value of the instructional materials, tools and activities (Gagné et al., 2005). The outcomes of evaluation determine whether the objectives have been achieved, the impact of the tools in the teaching and learning process, and the changes that are necessary in future delivery (Gagné et al., 2005; Peterson, 2003). To reach and collect this information, this study designed a strategy and developed various tools for data collection and analysis, as discussed in sections 3.4.4 and 3.4.5 of this chapter.

The ADDIE framework was used in both phases of this study (Phase 1 and Phase 2) to assist in the formation of instructional tools (educational interactive multimedia software).
First, the ADDIE framework was used in the planning of the instructional design of the first multimedia tools (Tools 1 in Phase1). The framework proved useful for the processes of development of the educational application (Tools 1), as will be discussed in Chapter 5. The ADDIE model’s final stage (evaluation) in Phase 1, revealed where revisions were required in each of the other four components of the ADDIE for Phase 2. Figure 3.6 illustrates the operation of the ADDIE model in the two phases of the study.

3.4. Research procedure

This study was conducted in two phases (as stated above) in Western Australian primary schools. The first phase took place over a period of two school terms in 2012. This phase involved trialling the educational software based on the proposed framework, with a special emphasis on the use of multimedia and interactivity. From the findings in Phase 1, sets of new tools were developed for Phase 2 of the study. The second phase started in February 2013 (the first term of school in Australia) and covered three school terms. Over the period of these two phases, this study employed 31 primary teachers in 17 different schools in Western Australia (see the Participants section, below).

The steps in the procedure of the study are summarised in Figure 3.9. Step 1 involved the study of different sources of contextual information (such as the Australian Curriculum,
existing mathematics software, current mathematics pedagogies) and the selection of the instructional design model (as outlined in section 3.3). Based on analysis of the different categories and information from Step 1, as well as taking into account the elements of the Bloom/Anderson taxonomy, the new framework was proposed in Step 2 (as discussed earlier in this chapter). The framework was used as a basis for the development of novel educational interactive multimedia software (Tools 1), which was trialled in Phase 1 of the study (Step 3). The findings from Phase 1 were analysed in Step 4 and the outcome informed the second phase of the study (Step 5). The data analysis and findings from Phase 2 resulted in the final evaluation and implications of the study (Step 6), which provided answers to the research questions (Step 7).

3.4.1. Selection of participants

This study attempted to involve 17 primary schools to participate in the project in Western Australia. Purposeful sampling was used for the recruitment of participant school for this study. Purposeful sampling involves selecting research participants according to the needs of the study (Gagné et al., 2005). It focuses on “selecting information-rich cases” that is
suitable for detailed research and explain the study’s questions in depth (Morse, 1991). The selection criteria for inclusion in this study were that the schools should have ICT facilities such as computers, interactive whiteboards and Internet access. Furthermore, the participant schools were selected from a diverse range of school from areas with different social and economic demographics, in order to investigate the value of the application in a distinct range of Western Australian primary schools. This included public, private (independent), specialist school for English as a Second Language students (ESL) and Remote Community schools located in metropolitan areas, suburbs, and semirural and rural areas.

3.4.1.1. Teacher participants

In total, 31 teachers within 17 different schools participated in the two phases of this study. In Phase 1, a list of Western Australian primary schools, type of schools, locations and general information about the schools were collected from the Department of Education of Western Australia and from the Australians Schools Directory (DEEWR, 2013) website. A request for expressions of interest in participating in the study was sent to 14 different schools in metropolitan area, suburbs, semi rural and rural areas. The request included a letter of invitation, background information about the project, along with the goals of the study. Schools that responded that they were interested in participating become the pool of potential participant schools. After initial contact was established with the school, the software application was presented to the school principal or/and deputy principal. Following gaining approval from the principal, if the school had a maths coordinator, the request was passed to them. This was followed by a meeting and the presentation of the software application to the maths coordinator(s). In the absence of a maths coordinator, the principals passed the research request to the relevant teachers (K to Year 4). Once teachers expressed interest in participating, the software application and teaching aids were presented to participating teachers in individual training sessions or small group workshops. Here, the functions of the software were demonstrated and examples of how the software might be used were presented. Participants also had time for self-directed exploration and learning, and for designing classroom mathematics lesson plans using different components of the application. Through this process, five schools were selected
to trial the Tools 1. Figure 3.10a illustrates the process of getting permission to trial the Tools 1 in schools in Phase 1.

In Phase 2, based on the results and findings of the Phase 1 (see Chapter 5) and participating teachers’ experience on using the first tools, the process of selection of participants for Phase 2 of the study were reformed. All participants teachers in the Phase 1, except two (who were on leave during Phase 2) expressed interest in participating in the second phase as well. The second software application and teaching aids (Tools 2) were presented to these teachers in individual training sessions. Then, these teachers (voluntary) invited other (K to Year 4) teachers in their schools to trial the program (‘snowball’ recruitment). The teachers presented the second software tools and teaching aids to other teachers and shared their own experience of using software tools in a staff development session in their school. Through this process a number of teachers (in the same school) who were interested to participate in the study were able to participate. For example in a particular school, just two teachers participated in the first phase, while in Phase 2, eight teachers expressed their interest to use the tools. The research project was also discussed informally among other schools in Western Australia through different teachers’ professional development sessions. Furthermore, the researcher presented the research project and software tools in a teachers’ professional development (PD) workshop, named, Essential Elements of Early Numeracy course, which was held in Western Australian in early 2013. Interested teachers contacted the researcher for further information on accessing the software tools and the possibility in participating in the study.

Through these processes, 24 schools from around Western Australian with different social and economic backgrounds become the pool of potential participant schools for Phase 2 of the study (Figure 3.10b). The software was offered to all 24 schools, but only 12 of these schools were selected for participation in Phase 2, based on the above mentioned criteria and consideration to the researcher’s limited time for carrying out the teachers’ training and conducting the necessary observations and data collection.
In both phases of the study, selected participant teachers came from multiple grade levels (K to Year 4). The teachers had a wide range of experience with some being in their first two years in the profession and other with many years of experience (up to 48 years). Also, their experience in using technology and their comfort levels in using technology (Technology Knowledge) varied considerably. This selection has been made to investigate the pedagogical and technological evaluation of the application in different setting with a diverse range of users.

3.4.1.2. Formative evaluation participants

Formative evaluation was conducted extensively at different stages of this study. Five adults, one with a computer science background, two early primary mathematics educators and two primary school teachers were invited to participate in formative evaluation of the tools at different phases of design and development such as Alpha testing. Two primary school students also trialled and tested the software constantly to inform the developer about the components that worked and those that did not work.
University of Western Australia’s Early Childhood and Primary School pre-service teachers also participated in the formative evaluation of the software application. As previously mentioned (in development phase of ADDIE) a substantial formative evaluation of the tools was conducted among these participants during Phase 1 of the study in 2012 and during Phase 2 in 2013 (24 pre-service teachers in each phase) before the novel tools were implemented in the natural setting (schooling system).

3.4.2. Tools and materials

Employing multimedia technology for presenting multiple representations, and using children’s literature for teaching mathematics, are the essential parts of this study. Based on the mentioned conceptual framework, along with the capability of multimedia technology, it has been possible to design and develop a series of interactive multimedia software as educational tools for teaching and learning mathematics concepts in the primary school classroom.

The educational application, My Maths Story, contained two series of interactive multimedia software and teaching aids named Tools 1 (in Phase 1) and Tools 2 (in Phase 2), which were developed by the author of this thesis in a computer science lab. Both tools applied the Bloom/Anderson learning objectives through the use of multimedia and interactivity for teaching and learning mathematics concepts. All parts of the software were designed to be used by classroom teachers, as well as by children, who can use the software independently, in pairs or in small groups.

Tools 1 were designed and developed based on the proposed novel multimedia software development model. During this process, based on ongoing formative evaluation, some important experiences on the design of the tools were gained, which resulted in modification of the software and teaching tools. Based on the findings of Phase 1, the proposed software development model was found to be suitable as a basis for the development process of the second tools.

Tools 2 were built based on the experiences gained during process of Phase 1 and the technological and pedagogical evaluation of the first tools in the classrooms. Based on
these findings, the useful components and elements of Tools 1 were incorporated in Tools 2, along with the creation of several new components. For example in the technological evaluation of Tools 1, the screen layout design of the software was found to be easy to navigate and use, so this element was not changed for Tools 2.

The development process of the interactive multimedia software application is discussed in Chapter 4. Different components of the Tools 1 and Tools 2, the process of development and the evaluation findings and results are discussed in Chapter 5 (for Tools 1) and Chapter 6 (for Tools 2).

### 3.4.3. Data collection

Mixed method data can be collected from various sources of evidence (Creswell, 2013; Datta, 1997; Tashakkori & Teddlie, 2010). In order to address the research questions, instruments of several different types were developed to ensure the collection of a broad range of data to be available for analysis. The main collection methods used in this study were semi-structured interviews, questionnaires and observations of the use of the interactive multimedia educational applications in the real world setting.

The use of multiple data sources in this study was also based on the following considerations. Primarily, several data sources were employed to ensure that the information obtained would be trustworthy. The use of three different data sources was to allow triangulation of findings to take place (Creswell, 2013; Tashakkori & Teddlie, 2010). Hence, it was to ensure that the findings were credible and dependable, as one source could give confirmation to the evidence presented by another source. Alternatively, if conflicting evidence was found by the different methods, then further investigation could be followed until some form of resolution could take place. Additionally, the use of more than one method and instrument was seen as necessary in this study because they could give the researcher greater understanding of the settings as well as access to the participants thoughts on using the tools. Each method of data collection has its strengths and weaknesses, and the weakness of one method may be the strength of another. By using a number of data collection methods, a better understanding of the phenomenon can be achieved. Furthermore, various data collection instruments help to collect both forms of data (qualitative and quantitative) using...
the same construct or concepts (Creswell, 2013; Datta, 1997; Tashakkori & Teddlie, 2010). For example, if the concept being measured (or graded) quantitatively (questionnaires), the same concept is asked during the qualitative data collection process through the semi-structure (open-ended) interview.

Mixed method research can have more emphasis toward qualitative or quantitative finding, depending on the research questions, perspectives, how data has been collected and used, together with consideration to the sample size of both forms of qualitative and quantitative data and the amount of time that researcher can spend on data collection (Creswell, 2013). In this study, all teachers who completed the questionnaires were interviewed as well. Therefore, the number of participants (the sample size of both forms of data) is the same, with more emphasise on the qualitative based data to obtain and gather extensive information.

3.4.4. Data collection tools

3.4.4.1. Semi-structured interview

The primary means of data collection of this study was through the individual semi-structured interview with teachers. According to Savenye and Robinson “An interview is a form of conversation in which the purpose is for the researcher to gather data that address the study’s goals and questions” (Savenye & Robinson, 1996, p. 1056). The purpose of the semi-structured interviews was to gather participant teachers’ reflective views on using the interactive multimedia software in teaching and learning mathematics. A series of questions was developed to guide the researcher during the interview. The interviews occurred towards the end of the trial period. A series of questions were asked in order to carry out a pedagogical and technical evaluation of the multimedia application, some of which were directly answerable (closed-questions) and others were open-ended to allow for in-depth responses (Creswell, 2013).

The semi-structured interview, shown in Appendix A, included four major areas, beginning with some broad questions which were mainly related to the teachers’ experiences in using the software and associated teaching aids, any challenges they may have faced during
the use of the software, and how they thought the software designer might minimise these challenges. In the second part of the interview, participants were asked about the technical features of the software and factors associated with technology integration, including questions about the interface and layout design, the multimedia elements and functionality. These two parts mainly addressed the technological evaluation criteria of the developed tools. The details of technological evaluation criteria are discussed in section 3.4.5.1 of this chapter and presented in Table 3.1.

The third part of the interview focused on the pedagogical evaluation of the software, which included questions about how well the application might assist teachers to demonstrate mathematical concepts to children and to raise “why and how” questions related to the mathematics concepts being taught. Furthermore, teachers were questioned about their students’ engagement in the mathematics activities and how they shared and discussed a range of mathematical concepts when using the application independently or in pairs. Some examples of interview questions are, “Did this application assist you in demonstrating and explaining a range of mathematical concepts to your students? How?” or “How well were students able to create a simple maths concept story using the software? Could you please explain how?” The interviews ended with several concluding questions that elicited teachers’ responses to the possibility of using the application in their classroom again in the future, and whether they would use it instead of or alongside a traditional book. The pedagogical evaluation criteria are discussed in section 3.4.5.2 and shown in Table 3.2.

The semi-structured interview contained wide range of closed and open-ended questions through the mentioned majors areas, which were aligned with the different levels of the proposed conceptual framework and, in turn, addressed the research questions that guided this study. The validity of the teacher interviews was based on carefully designed questions that link back to research questions. The initial interviews conducted during Phase 1 of the study with 12 teachers after a trial that was two terms in duration, in 2012. Following these initial interviews, some minor changes were made to the interview questions for the second phase (Appendix A). The teacher interviews were audio recorded (with note taking as a backup) for the later data content analysis. The average time for the interviews averaged around 40 minutes.
3.4.4.2. Questionnaire

Questionnaires were one of the research instruments, and consisted of a series of closed and open-ended questions. This was completed by the research participants (teachers) for purpose of gathering information (Creswell, 2013; Punch, 2009; Tashakkori & Teddlie, 2010). In open-ended questions, respondents provide and formulate the answer in their own words, whereas in closed questions, the respondent selects an answer from a given number of options (Creswell, 2009; Tashakkori & Teddlie, 2010).

Questionnaires were used as quantitative data collection instrument in this study. Two kinds of questionnaires were designed, one for pre-service teachers (for the purpose of formative evaluation) and another for participant teachers. Both questionnaires used similar language, terminology, scoring and coding, so they could be more easily compared during analysis. The pre-service teachers’ questionnaire was used as a means of formative evaluation of the tools before their implementation in the real world setting (Appendix B2). The participant teachers were asked to fill out a questionnaire toward the end of study period. All the items in the questionnaire instrument were carefully constructed so as to be in line with the interview questions and the purpose of the study. The questions in the questionnaire were designed as a set of closed questions, which followed logically from one to the next. However, the “Comments and Suggestions” section were included to allow respondents to fill in their view of the benefit and limitations of using the software in their own words or in the case where the provided response in the questionnaire were incomplete or inappropriate (Tashakkori & Teddlie, 2010).

The questionnaire instrument was used for two main reasons. First, this maintained consistency across all subjects with interview questions and hence facilitated comparison. Second, the answers to the questionnaire itself provided an important source of data, which, when combined with interviews data makes the result more concrete and efficient.

This study’s questionnaires were divided into three parts; namely, technical evaluation of the software, pedagogical evaluation of the software and overall comments relating to the use of the interactive multimedia software in the classroom. A Likert scale (Likert, 1932) was used in the first two parts of the questionnaire (technical and pedagogical evaluation); namely,
A as Strongly Disagree, B as Disagree, C as Undecided, D as Agree and E as Strongly Agree. The third section of the questionnaire (overall comments) included the categorical scale (Likert, 1932) (e.g., yes/no) questions such as "If you could choose, would you use this software and the teaching aids in your classroom in future? Yes/ No". Additionally (as mentioned above), participant teachers were encouraged to verbalise the reasons for their responses by writing their opinions in a comments and suggestions section at the end of each parts.

The initial questionnaire items were refined based on experience gained and teachers’ feedback on the Phase 1 of the study. Throughout this process, some unclear questions were rephrased and few repetitive questions removed. The final questionnaires, which were used in Phase 2, appear in Appendix B1.

3.4.4.3. Observation

Observation was another methods of data collection in this study. Observation is a data collection through which the researcher observes participants in a natural or structured environment (Creswell, 2013). Tashakkori (2010) mentioned observation as an important method because “people do not always do what they say they do” (p. 312). Another benefit of observation is that it can facilitate a form of data that can be used to verify and corroborate the information gain through other sources such as interviews and questionnaires. Furthermore, observational evidence is useful in providing additional information about the topic or understanding the context being studied as well as the themes emerging during the data analysis process (Tashakkori & Teddlie, 2010).

A systematic observation instrument was designed (see Appendix C) as a qualitative tool, which allowed the observer (the author of this thesis) to take field notes and record the use and interaction of teachers and learners with the educational software and teaching aids over the period of the trial. Accordingly, the observations were used as the third source of data to be analysed in process of data triangulation. The observer was present in classrooms throughout the school terms but did not actively participate in the classroom activities (non-participant, or direct observer (Tashakkori & Teddlie, 2010). Observations were conducted during the trial period where possible. A minimum of two sessions of observations per
participant (each between approximately an hour to three hours in duration) was conducted in the classroom where one observation usually occurred in the first session of using the software. These extensive observations allowed the researcher to collect data and record the interactions of teachers and learners with the applications in real world settings for the purpose of pedagogical and technical evaluation.

This study’s systematic observation instrument consisted of three parts, including pre-observation, observation and recording (watch and record) and post-observation. The instrument was designed to ensure consistency of the data being recorded. The pre-observation part provided context and information about classroom characteristics (such as class size, number of students), the teacher’s thinking on the lesson plan and instruction as well as the role of software and associated teaching aids in teaching and learning process.

The second part of the observation instrument guided the observer to watch, record and observe the use of the software during the lesson and learning activity in the classroom or computer lab. This included documenting the type of available technology/computer in the classroom or lab (interactive whiteboard, personal computer, laptop), use of application and class activity organisation (for example, teacher uses the application for demonstrating and explaining mathematical concepts or students use the application individually, in pairs or small group). Video and audio recordings and photos were taken during the lessons for detailed analysis.

Post-observation was the final part of the systematic observation instrument, which provided context for the data by verifying the information in the pre-observation form and how the software assisted the teacher to demonstrate the mathematical concept. On the post-observation form, the researcher also recorded observed obstacles to implementing the lesson plan in the classroom/computer lab or other relevant information.

3.4.4.4. Student feedback

As previously discussed, this study aimed to develop multimedia tools to be used for teaching and learning mathematics in the early primary years. Teachers were the main users of the tools; however, students (K- Year 4) also used the application in their mathematics lessons
individually, in small groups or in pairs. Thus, children’s experiences and feedback as users of the tools were taken into account in the evaluation of the tools that were developed for this study.

A simple student feedback form was designed with the assistance of two participant teachers during Phase 1 (Appendix D). The form was written in simple language to help children express and articulate their experiences in using the mathematics tools. The student feedback form was found to be a useful tool for collecting students’ responses; however, some participant teachers preferred to gather this information by asking questions to the whole class, or individually (face to face with children) after using the tools in the classroom. This verbal feedback was documented by the researcher (if she was available in the classroom as observer) or noted by the teacher and passed to the researcher. The collected feedback, either through the student feedback form or verbal feedback, was used as another source of data.

3.4.5. Data evaluation criteria

As mentioned above, a range of approaches and methods were used to collect data to investigate different aspects of developing and using interactive multimedia software for teaching and learning mathematics in the early primary years. In this research, quantitative and qualitative data were collected concurrently and all data preparation, collection, analysis and interpretation were centered within the pragmatic paradigm and the proposed conceptual framework. Each method of data collection was used to provide data on a number of criteria for technological and pedagogical evaluation and, in turn, to answer each of the research questions that guided this research. Therefore, the main part of the data collection was used to address the technical and pedagogical evaluation criterias of the software tools, which is discussed in the following paragraphs.

In the context of creating and evaluating of the multimedia software tools, as mentioned before, this study represents an approach that puts the user, rather than the system, at the centre of the process. This approach, called user-centred design (or user-centred approach), incorporates user concerns and requirements from the beginning of the design process and dictates that the needs of the user should be foremost in any plan, design,
develop and implementation decisions. Therefore, one of the central aspects of this study through this user-center approach was to develop educational multimedia software, which is useful to the users (in this case teachers and students). Usefulness is the issue of whether the developed software system can be used in primary educational context to achieve the desired goals and objectives (Carvalho, 2001). To evaluate this, in this study, the concept of usefulness breaks down further into technological and pedagogical criteria evaluation, which measures whether the design of the system was based on the user needs and actual uses of the tools achieved the goals that the study intend them to achieve.

3.4.5.1. Technical evaluation criteria

The most visible aspect of the user-centred approach is usability and utility testing, in which users work and interact with the software system and share their views and concerns with the designers and developers (Galitz, 2007; Microsoft, 2000). The technological evaluation process of this study mainly focused on these two aspects of the multimedia software system. Usability is “a quality attribute that assesses how easy a user interface is to use” (Galitz, 2007, p. 64) to perform prescribed tasks and also refers “to methods for improving ease-of-use” throughout the design process (Galitz, 2007; Nielsen, 2003). Whereas the utility refers to the “system or product’s functionality” (Galitz, 2007, p. 64) or, in other words, the ability of the system or product to perform a task or tasks (the system does what users want it to do). The more tasks the system or product is designed to perform, the more utility it has (Microsoft, 2000).

In the context of educational systems, Nielsen (1990, p. 148) has defined “pedagogical usability”, which is a sub-concept of utility, as the ability of a system to provide functions that correspond with the users’ needs. Pedagogical usability is also dependent on the goals set for a teaching and learning situation by teachers and students (Nielsen, 1990; Nokelainen, 2006).

Usability and utility are equally important in the design and development process and, together, determine whether a system or product is useful (Galitz, 2007; Nielsen, 2003). A software system may have a high level of usability but may not accomplish anything of value for its users, thus users would not have much reason to use it. On other hand, a powerful
software program that is difficult to use and navigate is likely to be resisted by its users (Galitz, 2007; Microsoft, 2000; Nielsen, 2003). In this study, usability and utility were seen to be equivalently important.

Different aspects in usability testing have been identified and investigated in several studies to address the challenges of designing a system that meets users’ needs (Booth, 1989; Nielsen, 1993; Shackel, 1990; Smith & Mayes, 1996). However, this study evaluated the multimedia software’s usability and utility according to Nielsen’s (2003) quality components. Nielsen (2003) has suggested that usability can be defined by five quality components:

- **Learnability:** How easy is it for users to accomplish basic tasks the first time they encounter the design?
- **Efficiency:** Once users have learned the design, how quickly can they perform tasks?
- **Memorability:** When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- **Errors:** How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction:** How pleasant is it to use the design?

(Nielsen, 2003).

Nielsen also stated utility (or pedagogical usability) as key quality attributes to be taken into account in a design process. This can be studied through use of the same user research methods that are used to study usability.

This study evaluated the multimedia tools’ usability and utility according to the Nielsen (2003) quality components from questionnaires, interviews, and observations data. The five attributes of usability addressed the technological evaluation criteria, while the utility studied the functionality of the usability attributes (technological evaluation criteria) as well as some pedagogical criteria (pedagogical usability).
Different open and closed questions were designed to capture participant teachers’ views and opinions on the different aspects of these five attributes. Observation also is an important method, which can offer a great deal of information about studying usability and utility (Dumas & Redish, 1999; Galitz, 2007; Microsoft, 2000; Nielsen, 2003). In this study, constant observations in classrooms helped the researcher to understand and investigate about what users do, where they succeed, and where they have difficulties with the system interface or functionality. The qualitative and quantitative data collected from participants, together with observations (methodological triangulation), allows findings to be corroborated thereby improving reliability as well as allowing a wider perspective to be taken. This includes to document the system usability and utility problems and to recommend solutions to the problems. Table 3.1 shows a summary of the items in the data collection instruments that intended to capture the usability and utility attributes and in turn, addressed the technological evaluation of the tools.

<table>
<thead>
<tr>
<th>Criteria Name</th>
<th>Items on Questionnaire</th>
<th>Items on Semi-structured interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learnability</td>
<td>Questions 6, 7, 11, 15 and 25</td>
<td>Questions 4, 5, 6 and 15</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Questions 5, 7, 8, 10 and 12</td>
<td>Questions 4 and 5</td>
</tr>
<tr>
<td>Memorability</td>
<td>Questions 3 and 6</td>
<td>Question 5</td>
</tr>
<tr>
<td>Errors</td>
<td>Questions 9 and 26</td>
<td>Questions 1, 2 and 5</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Questions 1, 2, 4, 13 and 14</td>
<td>Questions 1, 3 and 6</td>
</tr>
</tbody>
</table>

Table 3.1. Summary of links between data collection instruments and technological evaluation criteria

3.4.5.2. Pedagogical evaluation criteria

The study reported here, as previously mentioned, is based on facilitating cognitive learning objectives through use of children’s literature in mathematics education. The conceptual framework, which was discussed early in this chapter, was drawn from the cognitive learning objectives of the Bloom/Anderson taxonomy that, in turn, underpinned the design and development of the software tools. Therefore, a pedagogical evaluation was needed to investigate the pedagogical usefulness of the tools and whether it facilitated the needs of both teachers and students in junior primary classrooms. To achieve this, a set of criteria was created for the purpose of pedagogical assessment, addressing the various levels of
the conceptual framework, which linked to the Bloom/Anderson taxonomy. Additionally, these criteria gone further into pedagogical aspects by evaluating and investigating the other claimed benefits of the multimedia system and existing software limitations in Australia (as discussed in the Literature Review). This included criteria such as motivation, engagement, supporting multiple representations, flexibility, teaching mathematics through storytelling, curriculum alignment, feedback and collaboration. These criteria, which were used to evaluate and investigate the pedagogical aspects of the tools, are shown in Table 3.2.

The data collection methods and instruments employed to collect data on each of these criteria were the same as those used in the technological evaluation process (as displayed in Table 3.2). Responses to each question in the pedagogical section of the instruments linked to one or more criteria outlined above which, in turn, were used to evaluate the pedagogical usefulness of the tools.

<table>
<thead>
<tr>
<th>Criteria Name</th>
<th>Items on Questionnaire</th>
<th>Items on Semi-structured interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering and Understanding</td>
<td>Questions 17, 21, 22 and 24</td>
<td>Questions 12, 16, 17, 18 and 28</td>
</tr>
<tr>
<td>Applying</td>
<td>Questions 20, 29, 30 and 32</td>
<td>Questions 13, 15, 17, 18 and 28</td>
</tr>
<tr>
<td>Analysing, Evaluating and Creating</td>
<td>Questions 24, 27, 28 and 34</td>
<td>Questions 19, 20, 21, 22 and 28</td>
</tr>
<tr>
<td>Motivation</td>
<td>Questions 16 and 18</td>
<td>Questions 3, 10 and 13</td>
</tr>
<tr>
<td>Engagement</td>
<td>Questions 16, 18 and 35</td>
<td>Questions 3, 10 and 13</td>
</tr>
<tr>
<td>Multiple Representations</td>
<td>Questions 20 and 32</td>
<td>Questions 1, 10 and 13</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Questions 17, 20, 25, 32 and 35</td>
<td>Questions 1, 15 and 24</td>
</tr>
<tr>
<td>Storytelling</td>
<td>Questions 18 and 19</td>
<td>Questions 1, 10 and 11</td>
</tr>
<tr>
<td>Feedback</td>
<td>Questions 26 and 35</td>
<td>Questions 12, 21, 23 and 24</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Questions 23 and 33</td>
<td>Questions 14, 20 and 21</td>
</tr>
<tr>
<td>Curriculum alignment</td>
<td>Questions 19 and 31</td>
<td>Questions 8, 9 and 11</td>
</tr>
</tbody>
</table>

Table 3.2. The data collection questions link to different levels of the conceptual framework and other possible benefits of educational multimedia application
3.4.6. Data analysis and presentation

As mentioned earlier in this chapter, this research is based on convergent mixed method design in that two sets of data were analysed separately and then brought together (Creswell, 2013). According to Creswell, the challenge of this method is how to actually converge or to merge the data. Side-by-side comparison is one approach that can be used in mixed method analysis (Creswell, 2013). Here, the researcher makes comparisons within the discussion of the research, presenting the first set of findings then the second. The side-by-side approach was deemed to be appropriate for this study. The quantitative statistical results are reported first, then the findings from qualitative data discussed that either confirm or disconfirm the statistical results (Creswell, 2013).

To assist in the analysis of the large amounts of qualitative data, computer programs can be used (Creswell, 2009, 2013; Tashakkori & Teddlie, 2010). Computer software can assist in locating material easily, looking closely at data, facilitating the comparison of different codes, and visualising relationships between codes and themes (Creswell, 2013). The QSR NVivo program and the Microsoft Excel spreadsheet program were used in this study for data management and to organise, sort and search information in database, as well as to facilitate the comparison of different codes. The following paragraphs explain the data analysis strategies used in this study.

3.4.6.1. Analysis of questionnaires

Likert-type items were used in this study’s questionnaire to gain participant views about the usefulness of the multimedia software. The questionnaire scales ranged from a group of categories (least to most) including, strongly disagree, disagree, undecided, agree and strongly agree.

In analysing data from a Likert-type scale, an important consideration is that the statistical procedures direct the researcher to answering the research questions meaningfully whilst maintaining the richness of the data (Allen & Seaman, 2007; Clason & Dormody, 1994). To understand and select the most appropriate statistical procedures, it is necessary to identify the level of measurement associated with the quantitative data (Ary, Jacobs, Razavieh, &
Sorensen, 2010). The level of measurement (nominal, ordinal, interval, and ratio) influences the type of analysis that can be used (Allen & Seaman, 2007; Ary et al., 2010; Boone Jr & Boone, 2012). In the study reported here, the questionnaire collected interval (five-point categorical scale) and nominal data (Yes/No scale). Interval data is defined the type of data in which “ordering and distance measurement are possible” (Allen & Seaman, 2007). Interval data is continuous and has a logical order and standardised differences between values, but do not have an absolute zero (Boone Jr & Boone, 2012; The Pell Institute, 2013). Nominal data is basic classification data, representing categories without numerical representation (Allen & Seaman, 2007).

In this study, descriptive statistical methods were employed to describe the main features of the collected data. Analysis of data through descriptive statistical methods was identified as an appropriate technique for the quantitative data analysis in this study, based on the identified levels of measurement (interval and nominal data) and the study’s sample size restrictions (n=12 in Phase 1 and n=19 in Phase 2). This method was used to organise and present the collected quantitative data in tabular form. The quantitative data analysis procedures used in this study are outlined below.

1. Enter and organise data

The data collected through the questionnaire was entered into a spreadsheet software package. Microsoft Excel computer software was used to enter data into an electronic format and for data management purposes. In this process, participants were assigned to a unique participant ID and the responses were organised by the questionnaire’s item number. Figure 3.11 shows an example of a data spreadsheet.
2. Code Data

For quantitative data analysis using computer software, every response item on the questionnaire needs to be coded as a numerical value, except narrative text (Creswell, 2013, The Pell Institute, 2013). A codebook was developed that listed each question name, all of the answer options for each question, and the numerical code assigned to each answer option. Figure 3.12 shows the codebook entries for the data shown in sample spreadsheet provided above.

<table>
<thead>
<tr>
<th>Participant ID: range T1-T19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions: range Q1-Q35:</td>
</tr>
<tr>
<td>1 = A (strongly disagree)</td>
</tr>
<tr>
<td>2 = B (disagree)</td>
</tr>
<tr>
<td>3 = C (undecided)</td>
</tr>
<tr>
<td>4 = D (agree)</td>
</tr>
<tr>
<td>5 = E (strongly agree)</td>
</tr>
<tr>
<td>Questions: range Q36-Q38:</td>
</tr>
<tr>
<td>1 = Yes</td>
</tr>
<tr>
<td>2 = No</td>
</tr>
</tbody>
</table>

Figure 3.12. The developed codebook for the questionnaire
3. Cleaning (validation) of data

Data cleaning is a process of checking data for errors and accuracy. Omitting this step may severely influence results (The Pell Institute, 2013). This study used different cleaning methods for maximising accuracy and detecting all possible errors in the quantitative data. Spot-checking and eye-balling are two approaches that were used in the data cleaning process in this study.

The spot-checking technique involves “comparing the raw data to the electronically entered data to check for data-entry and coding errors” (The Pell Institute, 2013). To spot-check quantitative questionnaire data, several participants’ completed paper questionnaire were selected and compared with the data on the electronic spreadsheet. If an error was found in the first round of spot-checking, another round was carried out.

The eye-balling technique includes “reviewing the data for errors that may have resulted from a data-entry or coding mistake” (The Pell Institute, 2013). For example, question 36 from the questionnaire reads: If you could choose, would you use this software and the teaching aids in your classroom in future? Participants can only respond to this question with a “Yes” or “No”. According to the codebook, “Yes” is assigned a value of 1, while “No” responses are assigned a value of 2. Therefore, any number other than a 1 or 2 in the “Q36” column on the spreadsheet would be an obvious error. If such an error was found during this process, the researcher re-examined the original raw data questionnaire and entered that participant’s answer correctly.

4. Data tabulation

According to Connor, “Tabulation involves the orderly and systematic presentation of numerical data in a form designed to elucidate the problem under consideration”. In another words, tabulation is a means of summarising and presenting the given data in a systematic form in rows and columns (Sharma, 2011). Sharma, 2011, indicated that this sort of presentation “facilitates comparisons by bringing related information close to each other and helps in further statistical analysis and interpretation” (p. 44).

In this study, the tabulation technique was used for systematic presentation of numerical
data and prepared the ground for analysis and interpretation. Through this process a comprehensive picture of the quantitative data recognised and assisted researcher to identifying patterns.

5. Descriptive data

The study reported here also used a selection of descriptive data calculations to calculate and describe the data set in more details. The descriptive data used were:

- Mean
- Minimum and Maximum values
- Median

3.4.6.2. Analysis of interview and observation data

According to Creswell (2013), in general, the intent of qualitative data analysis is “to make sense out of text and image data” (p. 195) and it involves segmenting and taking apart data as well as putting it back together. He also points out that not all collected information can be used in the qualitative data analysis because of the rich and dense nature of text and image data. Thus, in analysis of data, the researcher needs to examine all data and focus on some of the data and disregard other part of it (Creswell, 2013).

Semi-structured interview transcriptions (text) and observation records (text, photographs, video recording, student feedback) were two sources of qualitative data in this study. As mentioned previously, the Nvivo computer program was used for sorting and managing qualitative data. The qualitative data analysis of this research was an ongoing process that happened throughout the data collection stage of the study and was carried over to the writing of the findings. The researcher iteratively and systematically read the data in order to get a sense of the whole database. Triangulation between the different sources of information was applied on the preparation and processing of the data. The whole process of the qualitative data analysis is conceptualised in Figure 3.13, using the data analysis approach suggested by Creswell (2013). The details of the process are explained in five steps in the following paragraphs.
1. Organisation and preparation of data

During the pre-analysis stage, a pool of raw data was created; including transcribed semi-structured interview, observation field notes, visual materials and video data. The transcription of the interviews involved listening to each participant’s recorded interview several times to ensure accuracy and to gain an overall impression of the data. If unclear statements were noticed during this process, the researcher returned to the participant teacher for clarification. The clean data were sorted, and then imported into Nvivo software, which assisted and accommodated the analytical process of the study. The participant teachers’ interviews, the classroom observations and all related materials were saved under their unique ID (the same ID used for questionnaire data). A screen capture of the Nvivo program is presented in Figure 3.14.
2. Reading through the data

The collected data were read and examined several times to grasp a general sense of the information and understanding the overall meaning of collected data. Through this process, some general ideas about participants’ perspectives and their thoughts on using the program were generated. At this stage, the researcher also wrote some notes in margins of the transcribed interviews and filed note data. Parallel with this, visual records, including photographs and video data, were studied.

3. Coding the data

Codes are described as “tags or labels for assigning units of meaning to the descriptive or inferential information compiled during a study” (Miles & Huberman, 1994, p. 56). In qualitative data analysis, a code is most often a word or short phase which represent participants’ thoughts in the study (Creswell, 2013; Saldana, 2012). The coding process involves putting segments of text data or images in to categories and labelling those categories with a term (Creswell, 2013).
Codes can: a) be developed a priori from existing theory or concepts (theory/concept-driven); b) emerge from the raw data (data-driven), or; c) grow from a specific project’s research goals and questions (structural) (Ryan & Bernard, 2003). Creswell also mentioned these different types of codes as predetermined codes (the first categories), emerging codes (the second categories), or some combination of predetermined codes, emerging codes (the third categories).

In the case of using predetermined codes based on a theory or concepts being examined, the development of a qualitative codebook is recommended (Creswell 2013; DeCuir-Gunby, Marshall, & McCulloch, 2011). A qualitative codebook is a table that contains a list of predetermined codes that researcher use for coding the data (Creswell, 2013, p. 199). Codebooks may change and revise some definitions during the data analysis process while the researcher gains clearer insights about the qualitative data. Thus, the codebook development process is an iterative process (Creswell 2013; DeCuir-Gunby et al., 2011).

The study reported here, as mentioned earlier in this chapter, introduced a new conceptual framework based on cognitive objective of Bloom/Anderson taxonomy. The framework underpinned the design of new multimedia software. It has highlighted when a study is based on a concept or theory, that “theory or concepts should play a critical role in the creation of a codebook” (DeCuir-Gunby et al., 2011, p.152) and generating codes data is about meshing all of the theoretical underpinnings of the study with the data that has been collected (Creswell 2013; DeCuir-Gunby et al., 2011). Thus, in the case of this study, a critical feature of codebook creation entailed detecting conversations, words, images and information about the conceptual framework and other mentioned criteria. This study aimed to examine the cognitive learning objective concepts (pedagogical criteria) of the framework as well as the usefulness of multimedia application claimed in the research literature and the mentioned technological criteria. Therefore, creating the concept driven codes (predetermined codes) to assist in the coding was a necessary step of the data analysis process. Furthermore, while engaging in data analysis, the researcher identified and developed some other codes on the basis of emerging information collected from participant (emerging codes). Consequently, to perform a preliminary analysis, this study primarily used the predetermined codes, but also used some emerging codes for
categorising the participants’ responses in their own language (also called in-vivo) about the use of the multimedia applications in their classrooms. Figure 3.15 shows the visualisation of the coding process used in this study.

Figure 3.15. Process of qualitative data coding

The predetermined codes were generated from the conceptual framework that guided the research, from the research literature, as well as from technological usefulness criteria (usability). Developing predetermined codes followed the Boyatzis (1998) procedures, which involved three steps: (1) generate the code; (2) review and revise the code in the context of the data, and; (3) determine the reliability of the coder and the code (Boyatzis, 1998). In determining the potential codes and reliability of the codes and the coder, a series of discussions between the researcher and her supervisors took place. However, additional codes emerged as the researcher read the interview transcripts and examined other qualitative data.

After several passes through the text, coding iterations, extensive investigation and discussion with supervisors, the study’s qualitative codebook was developed, and used three components: code name, full definition (an extensive definition that collapses inclusion and exclusion criteria), and keywords. A total of 19 codes were created based on the research criteria and emerging data. Table 3.3 shows a sample of codes that were created for capturing cognitive learning objectives criteria. A full version of the developed codebook is available in Appendix E.
<table>
<thead>
<tr>
<th>Code Name</th>
<th>Definition</th>
<th>Key Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Recall previously learned information.</td>
<td>defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognises, reproduces, selects, states.</td>
</tr>
<tr>
<td>Understanding</td>
<td>Comprehending the meaning, translation, interpolation, and interpretation of instruction and problems. State a problem in one's own words.</td>
<td>comprehends, converts, defends, distinguishes, estimates, explains, extends, generalises, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarises, translates.</td>
</tr>
<tr>
<td>Applying</td>
<td>Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.</td>
<td>applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.</td>
</tr>
<tr>
<td>Analysing</td>
<td>Separates material or concepts into component parts so that its organisational structure may be understood. Distinguishes between facts and inferences.</td>
<td>analyses, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Make judgments about the value of ideas or materials.</td>
<td>appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarises, supports.</td>
</tr>
<tr>
<td>Creating</td>
<td>Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.</td>
<td>categorises, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organises, plans, rearranges, reconstructs, relates, reorganises, revises, rewrites, summarises, tells, writes.</td>
</tr>
</tbody>
</table>

Table 3.3. Sample from qualitative codebook
After the predetermined codes were developed, they were used to examine the data in context. The codes were applied to the data so that the researcher could then describe and make sense of “how participants had constructed their experiences and perceptions” (Guest & McLellan, 2003, p. 191). As suggested by Boyatzis (1998), the created code labels were conceptually meaningful, clear and concise, and close to the data. Some revision was required on some of the code labels.

During the coding process, memos from the raw data were generated to capture short phases or ideas from participants, which in later stages helped to describe and define concepts or theoretical propositions. For example, in the cognitive learning objectives, the code for remembering and understanding as in Bloom/Anderson taxonomy raised the following memo:

“They [students] can remember and recall maths concepts through the motivation of story and story characters. My children been engaged in the story very well and they remember the story well and if I brought something that we read it before or done it, they can recall it… when they remember the fact, I manipulated the activity and made it a bit more difficult and ask them to solve the problem” Year 2 teacher.

The mentioned process of assigning of codes (predetermined and emerging codes) to raw data, allowed the researcher to be more engaged in the data reduction and simplification. Further, the data was examined with the research questions, conceptual framework, the initial literature review and technological and pedagogical criteria in mind. Through this coding process, the researcher made better connections between ideas and concepts. Applying codes to the raw data enabled the researcher to begin examining how the data supported or contradicted the conceptual framework that guided the research.

4. Interrelating themes

The labelled codes were used to create description for the study’s two main evaluation criteria: technological and pedagogical. The codes were used to generate a number of categories (themes), based on multiple perspectives from individual participants and supported by diverse quotations and specific evidence. The themes included: 1) **Technological satisfaction in using the multimedia tools**; 2) **Applying cognitive learning**
objectives based on the Bloom/Anderson taxonomy; 3) interactive multimedia technology for supporting mathematics pedagogies; 4) Curriculum alignment, and; 5) Perception of pedagogical practices on adapting new technology. The first four themes were generated from the predetermined codes and the fifth theme created from emerging codes.

3.4.6.3. Presentation of findings

The findings of the research study are presented in Chapter 5 (for Phase 1) and Chapter 6 (for Phase 2) to evaluate the technological and pedagogical capabilities of the developed multimedia tools. To substantiate and contextualise the presentation of findings, the reporting draws heavily on direct quotations of participant teachers and students in both phases of the study.

As mentioned earlier, the first multimedia software (Tools 1) was developed and trialled in Phase 1 of the study. Also, Phase 1 was conducted to examine and investigate the practicality of the proposed conceptual framework, the selected instructional system design model and the data collection methods and instruments. Thus, the qualitative and quantitative data of this phase was analysed in the manner explained above and is presented in the two main categories of technological and pedagogical evaluation. The findings of this phase informed the researcher of the need for conducting the second phase and all necessary adjustments and refinements to the developed tools and instruments.

In Phase 2, based on the findings and experiences gained in previous phase, the full process of data analysis was applied through the data analysis steps. The findings of Phase 2 are presented through the five developed themes, which are discussed in previous section. The most frequently discussed themes selected to organise the findings about teachers’ views on using the multimedia application on their teaching and learning process. The themes discussed in order that provides logical connections among themes not in descending order of frequency. Within each section, the researcher made an assertion and provides evidence from the collected data (e.g. interviews) to support it.
3.4.7. Research trustworthiness and rigour

A mixed method research study needs to consider the trustworthiness and rigour of the research design, which involves consideration of the validity and reliability of the data collection instrument, the process of analysis and the interpretation of results (Tashakkori & Teddlie, 2010; Yin, 2009). In mixed method research, qualitative validity or trustworthiness refers to check the accuracy of the finding by employing certain procedures (Creswell, 2009, 2013; Tashakkori & Teddlie, 2010) while qualitative reliability often refers to the coding of qualitative data compared among several coders (Creswell, 2013). Quantitative validity refers to the quality of the data collection instrument and interpretations and reliability refer to the consistency of participants score (Creswell & Clark, 2011). In this study, as mentioned in sections 3.4.6 (data collection) and 3.4.7 (data analysis), different processes for achieving validation and reliability were applied to each of the methods used in this research. As explained previously, the study was conducted in two phases. During the first phase, the proposed models and the instruments were piloted and necessary modifications were made to produce reliable instruments for Phase 2.

Triangulation, which has been used in this study, involves “seeking convergence and corroboration of results from different methods studying the same phenomenon” (Creswell, 2013; Creswell & Clark, 2011). Triangulation of various methods and data sources is a thus a means of enhancing trustworthiness and rigour in a mixed methods study (Tashakkori & Teddlie, 2010, p. 353). Additionally, in a mixed method study, transferability needs to be considered. This refers to the degree to which findings might apply or be transferable to settings outside the study (Creswell, 2013; Creswell & Clark, 2011; Tashakkori & Teddlie, 2010). In order to maximize transferability, a thorough, well-planned research design and the provision of sufficient information about the study to allow the reader to establish the degree of similarity between the study and other research to which the findings might be transferred, or can be generalised to fit other settings and contexts (Creswell, 2013; Creswell & Clark, 2011; Tashakkori & Teddlie, 2010). In this study, efforts were made to enhance transferability thorough describing the research context, the assumptions that were central to the study and through describing the research framework. Furthermore, detailed notes of the data collection design, the instruments and the analysis of data. This
should permit a reader who wishes to transfer the results to a different context to judge whether transferability is possible.

In addition, to increase dependability and reduce the risk of single researcher bias (Creswell, 2009, 2013; Tashakkori & Teddlie, 2010), the reasoning and the process taken in collecting and analysing data have been made explicit to provide a clear audit trail of the investigation process. As previously discussed, using Nvivo software has the advantage of simplifying retrieval and increasing transparency of the process of coding and conceptualising data. The process of data collection, documentation and Nvivo coding were maintained in such a way to enable others to understand the path taken by the researcher.

In this study, credibility, which concerns the truthfulness of the data collected, was enhanced through a number of strategies including an extended period of data collection. For this study, data were collected over a period of five school terms during two phases of the research (two school terms during Phase 1 in 2012 and three school terms during Phase 2 in 2013). Another way was to spend prolonged time in the field (Creswell, 2013) and persistent observation in a natural setting, as explained in the observation section of this chapter. Through this strategy, the researcher developed an in-depth understanding of the phenomenon under study, allowing her to convey detail about the participants and their setting that contributes to credibility of the study. The use of multiple data collection methods is another way to achieve credibility (Creswell, 2013). This study used a variety of data sources including semi-structured interviews, questionnaires and observations. The recorded interviews were listened to and briefly analysed shortly after conducting interviews and the researcher returned to the participant teachers to clarify their statements and to ask them to check the accuracy and credibility of the account after transcription and analysis. Finally, ‘peer debriefing’ (locating a person, other than researcher, who reviews and asks question about the qualitative study) (Creswell, 2013; Tashakkori & Teddlie, 2010) was carried out regularly throughout the data planning and gathering phases with participants and the research supervisors. This strategy strengthened the analytical process and the credibility of the study.
3.4.8. Ethical considerations

This research required ethics approvals from the University of Western Australia and The Department of Education of Western Australia to ensure there were no adverse effects on the health or wellbeing of any participating teachers and students.

The ethics approval process required the researcher to supply several documents, including copies of the original research proposal, the researcher's Working with Children Certification, the questionnaire and semi-structured interview instruments and the information and consent letters that would be provided to school principals, teachers, students and their parents. For conducting pre-service teachers’ formative evaluation, only approval from the University of Western Australia’s Ethics Committee was required. Approvals were granted from both ethics committees and did not require any changes to the research approach. The University of Western Australia Ethics Committee required annual reports on the research progress. The reference number given to this research by the Department of Education was D12/0273096. The reference number giving to this research by the Human Research Ethics Committee of the University of Western Australia was RA/4/1/5231.

The standard protocols for confidentiality, anonymity, informed consent form and risk were followed to ensure that all participants were treated ethically at all times. To maintain confidentiality, the participant teachers were identified by an ID and grade level. All participants were aware that they could withdraw from the study at any time. The researcher’s contact details, a letter of invitation and a consent form (Appendix F) were provided to school principals, participant teachers, children and their parents to ensure they were are all aware of the aims and procedure of the study. Written consent was obtained prior to each interview and the time, date and location of interviews were arranged according to participants teachers’ own convenience and comfort. Permission from parents and children who were going to be observed by the researcher was also gained before researcher observation commenced in classrooms. An information letter was given to the pre-service teachers and written consent was also obtained prior to the formative evaluation gathering.

All participant teachers gave permission for photos to be taken around the classroom, providing no children were identifiable in the photos (unless the permission obtained from
children and their parents individually). If any students were potentially identifiable in a photo that the researcher wanted to use for a conference presentation or this thesis, the researcher used computer software such as Adobe Photoshop and Adobe Fireworks to blur their faces.

The researcher also obtained a National Criminal History Record and a Working with Children Check before starting this research.

### 3.5. Chapter conclusion

This chapter has presented the research methodology and the research approach taken to conduct this study. The chapter introduced the conceptual framework, which is based on the cognitive learning theory, and more specifically, the Bloom /Anderson taxonomy. Next, the chapter described the systematic design process (Instructional System Design model) that was selected to reach the educational objectives. This chapter has also defined the details of research design, the procedure, the selection of participants and data collection tools. Ethical considerations and issues relating to research trustworthiness and rigour have also been presented.

Software development processes in general and their limitations in the development of educational multimedia application is discussed in the next chapter, followed by the presentation of a novel model for the development of the educational interactive multimedia software, which was designed and built for this study.
Chapter 4
DEVELOPMENT OF THE SYSTEM

The design and development of interactive multimedia software (as discussed in Chapter 3) as educational tools was a central element of this study. This chapter starts with an overview of the multimedia software development process and its difference to a common software development process, namely the Software Development Life Cycle (SDLC). In the absence of a universal educational multimedia software development model, a new model named IMDLC, which was adapted from a software engineering model, is proposed. The components of the model are discussed in this chapter.

4.1. Interactive multimedia software development

The development of educational interactive multimedia applications is a challenging and complex undertaking. In this type of software, knowledge of software development alone is not enough to develop such an application. Development of a software system usually focuses on the operational function of the software, while educational multimedia software development needs to comprise of: user interface development, software development, and media production (Engels, et al., 2003), with a robust theoretical underpinning informed by educational research (Figure 4.1) (Clark & Mayer, 2011; Frey & Sutton, 2010; S. Mishra & Sharma, 2005).
The purpose of educational multimedia software goes beyond merely combining media such as text, graphic, sound, animation and video to present information (Carter, 2002). To integrate creative design and operational functionality in multimedia software, collaboration between software engineers, user interface developers and media production experts is usually required (Engels, et al., 2003). These processes are complex and, like all intellectual and creative processes, rely on people making decisions and judgments (Sommerville, 2011). Therefore, developers of educational multimedia software need a framework to outline the software development process, creative media design and production. According to the literature, no universal methodology exists to guide multimedia software development (Barry & Lang, 2001; Frey & Sutton, 2010; S. Mishra & Sharma, 2005). Although several models have been proposed for multimedia systems development (Garzotto, Paolini, & Schwabe, 1993; Isakowitz, Stohr, & Balasubramanian, 1995; Lange, 1996; Pleuß & Hußmann, 2007; Schwabe & Rossi, 1995), it appears that these methods are not often used in practice (Barry & Lang, 2001; Frey & Sutton, 2010; Garzotto, et al., 1993).

Adaptation of general software engineering processes for multimedia development has been proposed and used in several multimedia development systems (Barry & Lang, 2001; Engels, et al., 2003; S. Mishra & Sharma, 2005). However, as stated by Mishra & Sharma (2005), these models, which are structured according to software engineering principles,
do not:

“actually focus on the most important aspect of educational software, namely, its teaching characteristics. Therefore, the models in this category are useful in describing the process for the development of educational software but have little value as tools for analyzing how useful particular educational software is for teaching purposes” (p. 117).

Therefore, a clear and detailed model is needed in describing the process for the development of educational software, as well as consideration of the teaching and learning environment in which the produced software going to be used.

The study reported here developed and implemented a new educational multimedia software development model. The model not only describes the technical process of the software development but also its value in the teaching and learning environment, understood through a comprehensive set of educational principles at different phases of the model itself, as well as through support from the ADDIE instructional system design (as discussed in Chapter 3). In the next section, an overview of a common software development process is discussed, followed by this study’s educational interactive multimedia software development model.

4.2. Software development lifecycle

A software development methodology is a structure imposed on the development of a software system, which helps system developers to plan, manage, and control the process of developing an information system. It is a set of related activities that leads to the production of a software product (Sommerville, 2011), including procedures, techniques, tools and documentation aids. A software development methodology is known as a Software Development Life Cycle (SDLC). The Software Development Life Cycle (see Figure 4.2) starts with a ‘requirements analysis’ and ends in the production of particular information technology products (Bassil, 2012; Davis, Bersoff, & Comer, 1988; Rajlich & Bennett, 2000; Thayer & Yourdon, 1997). This life cycle ensures discipline in the software development process and aims to produce a system that meets or exceeds users’ expectations, reaches completion within times and cost estimates (Parekh, 2006). Without a life cycle model, the
software development process is likely to be of poor quality that will be unlikely to result in a product that meets user requirements (Parekh, 2006, p. 653).

Many SDLC models have evolved over the years, each with its own recognised strengths and weaknesses (Bassil, 2012). Each system of software development methodology is not necessarily suitable for use by all projects (CMS, 2008; Sommerville, 2011) but is best suited to “specific kinds of projects, based on various technical, organisational, project and team considerations” (CMS, 2008, p.1).

4.2.1. The waterfall model

The waterfall model is one of the oldest SDLC models, and was proposed by Winston W. Royce in 1970 to describe a possible software engineering practice (Royce, 1970). Essentially, the waterfall model comprises five phases: analysis, design, implementation, testing, and maintenance. These phases need to be completed sequentially in order to develop computer software (Figure 4.3). However, a review takes place at the end of each phase to determine whether the software system is on the right path.
During the Analysis phase, also known as Software Requirements Specification (SRS), the system’s service, constraints, and goals are defined in consultation with system users. This includes the definition of purpose, scope, perspective, functions, software attributes, user characteristics, functionalities specifications and interface requirements. Furthermore, this phase defines in detail the various criteria and limitations of the design and operation of the software system.

The Design phase translates requirements into a representation of the software that can be assessed for quality before the generation of code begins. It is essentially a process of planning and problem solving for a software solution; it outlines the plan for a solution, which includes algorithm design, software architecture design, database design, concept design and graphical user interface design (Bassil, 2012).

The Implementation phase involves the realisation of requirements and design specifications into a set of software components through programming and deployment (Bassil, 2012; Sommerville, 2011). This phase is where the “actual code is written and compiled into an operational application” (Bassil, 2012, p. 2). In other words, it is the process of converting the specific requirements into software system.
The Testing phase is a process for checking that a software system meets the original requirements and specifications. It is tested as a complete system to determine whether the products satisfy the conditions imposed at the start and satisfies specified requirements (Bassil, 2012; Sommerville, 2011).

The Maintenance phase involves modifying a software after delivery (Bassil, 2012). It includes correcting errors that were not discovered in earlier stages of the life cycle, improving performance and quality of the system, as well as enhancing the system’s services as new requirements are discovered (Bassil, 2012; Sommerville, 2011).

Due to the success of the waterfall model, in both large and small software intensive projects, many software developers adopt this as their prime development model of SDLC process to plan, build and maintain their software products (Munassar & Govardhan, 2010; Sommerville, 2011).

### 4.3. Interactive multimedia software development lifecycle

Multimedia software engineering design is defined as “characterising content based on whether it is auditory or visual, statistic or dynamic, and sampled or described” (Fox, 2006). As with general software development, the process of multimedia software development can be divided into several life cycle steps. This normally involves a set of structured processes consisting of Analysis, Design, Development, Implementation and Evaluation. However, in multimedia software development, in addition to the application logic, multimedia applications usually provide a sophisticated user interface with integrated media objects. The development process therefore requires people with expertise in software design, user interface design, and media design.

In a multimedia system, if users have the ability to control the delivered elements and timing, the system is called an interactive system (Andleigh & Thakrar, 1995). For instance, a button on screen objects that will produce a response (for example, open a dialog box or make a sound when the end user clicks the mouse or touches them). This button is an interactive element in the multimedia application and authoring of the button involves defining the button appearance on screen, the location, and the type of action to occur. Software design, user
interface design, and media design experts will provide features to do each of these things. Therefore, in the development of interactive multimedia software, an additional framework is required. This framework not only assists in the system’s functional development but also helps designers to develop the content, identify the interactive elements, and design and use media to present content in the most effective manner to the users. The process and methodology need to be specifically designed to meet the requirements of the different experts in the areas of software design, user interface design, and media design.

The interactive multimedia educational software that was developed in this study (Tools 1 and Tools 2) followed a sequential Interactive Multimedia Development Life Cycle (IMDLC), as shown in Figure 4.4. This model was adapted from the traditional waterfall model of the software development life cycle (SDLC), which was discussed earlier in this chapter.

![Figure 4.4. Proposed IMDLC Model](image)

Similar to the waterfall model, the proposed interactive multimedia software development model (IMDLC) progresses the software development life cycle flowing increasingly downwards through several phases. The phases must be completed consecutively; however, the stages overlap and feed information forward and backward to each other. Thus, the process is not a simple linear model but is iterative.
As shown in Figure 4.5, the IMDLC model captures all steps of general software development phases with an additional consideration to the creative and media production as well as educational intents in each individual phase of the software life cycle. For example, the first phase of the waterfall model (Analysis), investigates and described user requirements and system specifications. These elements need to be studied in the first phase of IMDLC model (Planning and Conceptualisation) along with attention to graphical elements design, the planning for media production, and teaching and learning needs and requirements. The next section describes the activities that are involved in each phase of the IMDLC model.

4.3.1. The IMDLC model

Interactive multimedia software development necessitates the consideration of operational functionality as well as the content of the application blend with the creative thinking during the different phases of the software development life cycle. This involves a set of structured processes, consisting of: (1) Planning and Conceptualisation; (2) Design and Prototyping; (3) Production; (4) Testing and Evaluation, and; (5) Deployment and Maintenance.

4.3.1.1. Planning and Conceptualisation phase

The process of making multimedia software starts with an “idea” or “concept” (Redmond & Sweeney, 1997) which is the conceptual starting point. Conceptualisation involves identifying relevant information of the concept and the plan to define a multimedia system.
Then the system’s scope, content, goals, objectives, system type, target audience and technical specifications need to be defined. Requirements such as functional requirements, user requirements and performance requirements need to be studied during this stage. These requirements describe the expected behaviour of the hardware and software.

Because the interactive multimedia software in this study was for educational purposes, the information from the first phase of the ISD model (the Analysis section of ADDIE) was highly appropriate to be used for the user requirements analysis and for specifying systems objectives.

The results from this phase should be easy to understand by software designers, support the design phase and the transformation into code through multimedia authoring tools. Table 4.1 shows a summary of components that need to be addressed in this phase.
### Planning and Conceptualisation phase of the IMDLC model

| **Scope** | • The concept  
• The purpose  
• The educational message  
• The approach |
|-----------|--------------------------------------------------|
| **Objectives** | • Goal/s of the audience  
• Available resources  
• User requirements  
• Consistency system design and functionality  
• Creativity  
• Creation |
| **Target Audience** | • Audience background (with respect to age, education)  
• Audience preferences  
• Audience cultural  
• Audience constraints  
• Audience equipment (which will they use to access the multimedia system) |
| **System Types** | • Electronic books and magazines  
• Kiosks and information centres  
• Multimedia databases  
• Corporate training  
• Interactive education software  
• Interactive games  
• Interactive music  
• Interactive movies  
• Interactive art and performance  
• Presentations and communications |
| **Technical Specification** | • Functional requirements  
• Hardware and software required  
• Delivery media  
• Installed base  
• Storage capacity  
• Speed |

*Table 4.1. Summary of the components in the IMDLC’s planning and conceptualisation phase*
4.3.1.2. Design and Prototyping phase

The Design phase bridges the gap between audience requirements and multimedia software production. It is a process of visual thinking or visualisation to create an overall conceptual design of the system to be developed. Simplicity, consistency, user involvement and efficiency always need to be considered in the design of any educational computer systems (Clark & Mayer, 2011; Galitz, 2007).

As discussed in Chapter 2, Clark and Mayer (2011) established a set of principles for the design of educational multimedia systems. Their six principles of the cognitive theory of multimedia learning (see Table 2.1) were used to guide the design and development of this study’s educational multimedia software. These principles informed the designer (researcher) in the incorporation of multimedia components (image, audio, animation, written and spoken narration) in order to prevent an overload of cognitive stimulation which can impede learning (Clark & Mayer, 2011; Mayer, 2003).

1. Design

The educational interactive multimedia software applications (tools) that were designed and developed as part of this study followed a series of steps in the design phase of the IMDLC model including: brainstorming, storyboarding and script writing, flowcharting, user interface layout design and graphics elements design, content development/production, paper design or blueprinting.

Step 1, Brainstorming: The Design phase often starts with a brainstorming session. Brainstorming is a dynamic process of gathering ideas and exploring possibilities without judgement or constraint (Mišic, 2002). The result in a collection of ideas and solutions that become the foundation for both the design and the prototype developed from it.

Step 2, Storyboard and script writing: Storyboarding is “the process of defining the message and describing the user interaction with the content and the application” (Abd. Aziz, 2012, p. 25). In other words, the storyboard is a sequence of simply drawn pictures that visually depict a program in scenes or screens (S. Mishra & Sharma, 2005), while scripting is design content in textual form.
Scripting for multimedia and the preparation of storyboarding is a highly systematic process that involves a complex effort to develop panels for screen layouts that describe content, flow and format (Abd. Aziz, 2012). A clear storyboard is the key to ensuring that the subject matter is comprehensively covered in a fashion that the anticipated end user can learn. Each key screen should have a brief description of the scene, user interaction and dynamics elements, such as sound, animation and graphic (Figure 4.6).

**Figure 4.6. Sample of storyboarding for Tools 1**

**Step 3, Flowchart**: While the storyboards show the details of each screen, the flowchart shows the sequence and flow of the multimedia program, or the complete outline for the program. It outlines the structure of the program, showing all of the screens and the connections from each screen to the others.
Flowcharts are used to design the structure and the possible user interaction pathways and connections, expressed through labelled boxes and directional arrows (Figure 4.7). It provides the logical design from which the much more detailed storyboards will naturally flow. In other words, the flowchart complements the storyboard.

![Flowchart](image)

*Figure 4.7. Tools 1’s flowchart design*

**Step 4, User interface design and graphics elements design:** The user interface is the most important part of any computer system (Galitz, 2007). It plays a significant role in the process of learning because “it essentially determines the way in which learners will formulate their ideas” (S. Mishra & Sharma, 2005; p. 125). Also, cognitive load on computer users can be significantly reduced through the implementation of a well-presented graphical user interface (Galitz, 2007). For example, eliminating unnecessary information from screens and properly formatting and grouping information can reduce cognitive load.

User interface design is a division of human-computer interaction (HCI) study. Human-computer interaction is the study, planning, and designing of interaction between people and computers to ensure that the user’s needs are satisfied in an effective way (Alan, Janet, Gregory, & Russell, 2004; Galitz, 2007). It is the part of a system that can be seen, heard and touched as opposed to the software code, which is invisible and hidden behind screens, keyboards, and the mouse.
A variety of factors need to be considered in an effective educational user interface design, such as: user expectation, user physical limitations, technical characteristics and limitations of the computer hardware and software. The goals of interface design are to make working with a computer easy, productive, and enjoyable (Galitz, 2007, p. 1).

Keeping the Clark and Mayer principles in mind, the user interface design of multimedia educational software of this study considered five main elements in the interface layout design, namely: colour, typography, icon, navigation and screen area.

- **Colour:**

According to Galtiz (2007): “Color [colour] adds dimension, or realism, to screen usability. Color [colour] draws attention because it attracts a person’s eye. If used properly, it can emphasize the logical organization of information, facilitate the discrimination of screen components, accentuate differences among elements, and make displays more interesting and attractive. If used improperly, color [colour] can be distracting and possibly visually fatiguing, impairing the system’s usability”.

The proper use of colour is believed to be one of the factors that can attract users using the application (Woodland & Szul, 1999), and can improve users’ performance, enhance the visual search and the attention given to information (Galitz, 2007; Woodland & Szul, 1999).

Colours used in the interface design of this study were based on the Galtiz (2007) colour categories, which are: (a) colour used as a formatting aid in structuring a screen; (b) visual code to categorise and identify information or data, and; (c) used to portray objects naturally and make a screen more appealing to look at (Figure 4.8).
Figure 4.8. Sample of colours used in the interface design - Tools 2

- Typography:

Typography or typeface is the name of a font type, such as Times New Roman, Arial, Verdana, or Helvetica. A font has several qualities, including size (Times New Roman 16-point or Arial 12-point) and other characteristics, including case (upper, lower, and mixed), type (serif and sans serif), and styles such as bold, italic, outline or shadow.

To achieve the best reading speed, the typography principles of multimedia interface design recommend using simple, common, and familiar fonts. It is also advisable to avoid using more than two font families (Galitz, 2007).

A very large number of fonts are available today; however, in this study, Victorian Modern Cursive and Helvetica fonts were the main fonts used. Victorian Modern Cursive script (Evely, Nichol, & Laughlin, 1985) is the handwriting style commonly taught in Western
Australian schools (see Figure 4.9). According to the Australian Curriculum, children need to use joined letters of the font and develop a handwriting style that is becoming legible, fluent and automatic (ACARA, n.d.).

The Helvetica typeface is one of the most appropriate fonts for use in multimedia applications (Galitz, 2007; Roseli, Aziz, & Mutalib, 2010) as it is one of the few typefaces that work properly for both screen and print media. This font family was chosen for use in this study as a second typeface, mainly to define content (storybook text), instructional writing and in the production of print materials (the printed version of the storybook).

Figure 4.9. Victorian Modern Cursive typography in Tools 1

- **Icon:**

Icons are pictorial images, often used to represent a function or actions in a computer application. In designing an icon, concrete objects and abstract symbols are normally used to represent a meaning (Galitz, 2007; Sharp, Rogers, & Preece, 2007). An effective icon design presents a natural and meaningful association between the icon itself and what it
stands for. Little consideration is given to the effectiveness of icons in many current systems (Galitz, 2007). The result is too often a cluttered and confusing screen that is visually overwhelming to the user. Hence, proper icon design is important from an acceptance, learning, and productivity perspective and may speed learning (Galitz, 2007, p. 654).

In the design of effective icons, the context in which the icon is used and user expectations need to be considered. Galitz (2007) suggested several factors that can influence an icon’s usability, including: familiarity, clarity, simplicity, consistency, directness and efficiency. Figure 4.10 shows some icons that were created for this study’s multimedia software interface design.

Each icon in the software represents an action and requires the user to click on the icon or move an object over the icon, or operate both actions. For example, through clicking on the Book icon, the software reads the storybook, while rolling over an object on the + sign icon enlarges the object. Also, users can operate both actions on some icons, such as the Broom icon. Clicking on this icon will clean the current page, whilst rolling over an object on this icon (dragging and dropping) will remove (delete) the object.

**Navigation:**

Navigation involves the linking of various screens through the use of buttons, hypertext and icons. Navigation is a significant concept in every page or screen of a multimedia system, and each page must be well connected to each other to avoid users from getting lost in the system (Galitz, 2007; Sharp, et al., 2007). A well-structured navigation system enables users to work simply and easily, to make their way through the application as well as to access the information that they need easily and quickly. This results in reduction of cognitive load by focusing users' efforts on the content (rather than on operating the
tool). Since users of the multimedia software of this study were young children (as well as teachers), the navigation system was needed to be simple with a semi-linear structure, as shown in Figure 4.11.

- **Screen area:**

After the design process of the individual elements (such as icons, graphics, fonts), the next step was to organise and lay out these individual elements in a logical flow on the screen. A clear and consistent screen presentation can facilitate the user’s search for the required information and encourage quick and correct information comprehension (Galitz, 2007). A meaningful structure of the screen area is crucial to achieving the design goals of fast and accurate understanding and control execution, as well as avoiding overloading learners’ cognitive systems (Clark & Mayer, 2011; Galitz, 2007).

The screen structure of this study’s multimedia software was mainly divided into two main sections, namely: (a) navigational (composed of a collection of icons and interactive objects), and: (b) content areas (Figure 4.12).
Step 5, Content development/production: Content development follows the storyboarding process so that the story ideas and concept can be turned into an actual product. Content production depends on the availability of existing resources (for example, availability of mathematics storybook) or the need to create new materials. This process includes:

- the identification of new resources to be created or selected from existing resources;
- obtaining rights to use existing material;
- digitising of source pictures, audio, video into compatible formats;
- the production of original material including text, graphics, audio effects and animation;
- the formatting of source data for presentation in the system.

In the study reported here, both ways of content development, using the use of existing
resources and the creation of new resources, were applied. Phase 1 of development, which involved the production of the first interactive multimedia software (Tools 1), material was selected from existing resources (“One is a Snail, Ten is a Crab”, a counting by ‘feet’ book, written by April Pulley Sayre, Jeff Sayre, and Randy Cecil (2003), and permission for use of the resource was granted by the publisher. In the second phase (Phase 2), the author of this thesis created the new materials, “Count on Me! A Mathematics Adventure Storybook, written by Nasrin Moradmand (2012) and used the content of this book as a basis of the second interactive multimedia application (Tools 2).

**Step 6, Paper design or blueprint:** A paper design or blueprint for multimedia software is a graphical representation of a detailed plan or technical description and architectural structure. The paper design covers structural design, software strategy, and media production requirements. It consists of the storyboard, flowchart, user interface and functional specifications. The functional specifications cover various technical details such as the action on the screen, user interaction, buttons description and various media names (sound, animation and image).

**2. Prototyping**

A prototype is a miniature version of the final product. It is a limited implementation of a design and allows the designer/programmer to see all the design ideas and solutions in action. Prototyping is often used as proof of concept and helps simplify and improve the production process. The prototype should be reviewed by experts and surrogate users of the multimedia application for real world feedback (formative evaluation). This allows changes to the structure and behaviour of the system to be made before the production phase.

**4.3.1.3. Production phase**

The production process involves building the content into the multimedia software development environment, following the map provided by the blueprint (and storyboard). There are three main components that make up the multimedia production phase: graphic production, media production, and software programming.
Development begins with graphic design production, where graphical elements of the multimedia software in digital format are produced following the guidelines of user interface and graphic design from the design phase (step 5 of design) (Figure 4.13a). Media production is the next step of production, including the production of sound, video or animation (Figure 4.13b). This step must happen to some extent before software programming. Software programing is a task for writing programming (source code) to make the system interactive (Figure 4.13c). This step involves assembling all the media into a structure as described in the paper design (blueprint).
4.3.1.4. Testing and evaluation phase

The testing and evaluation phase is the process that tests and assesses a multimedia system to make sure it does what it supposed to do. Different types of testing are involved in this phase, including: functional testing, content testing, collateral materials testing and user testing. User testing (or usability testing) focuses on the operation and performance of the system from the end users’ (teachers and students) perspective. Usability testing may apply to prototype versions of the product, data elements such as graphics, audio, video segment and animation clips or to the completed multimedia software. The results of usability testing can be used to correct deficiencies and to improve the system by correcting problems with the operation, performance, or user interface design.

Alpha and Beta testing:

The IMDLC model, which was employed in the production of the software tools created for this study, used “Alpha testing” and “Beta testing” at different stages of the multimedia software development life cycle. These processes evaluated the new product through a protocol of testing procedures for verifying system functionality and capability. It conducted the Alpha testing relatively early in the development phase (prototyping) to evaluate and review the application’s concept, format, user interface, and page layout. During Alpha
testing, software is not fully functional. The software is therefore not sent to the end users but tested inside the organisation by a peer group. Four adults did the Alpha testing of the study reported here, one with a computer science background and three early primary mathematics teachers and educators.

The Beta testing happened just prior to the final release, mainly to find bugs and content mistakes. The application was distributed to a limited sample of users (two junior primary school children and four K-Year 4 primary school teachers) so that they could subject it to daily use and report any problems to the developer.

4.3.1.5. Deployment and maintenance phase

Once an application is tested and revised, it enters a deployment and maintenance phase, which includes the selection of distribution options and channels, production and distribution of supporting documentation and system maintenance.

Delivery system

This study used a blended strategy (a mix of different delivery media) for delivery of the multimedia application. This strategy recognised the need to allow flexibility and strengthen the teaching and learning process by providing multiple ways of delivery. In this way, each media approach become a complementary to others, forming an integrated approach (S. Mishra & Sharma, 2005). The program content was delivered in print (mathematics storybook and hands on material), multimedia CD (interactive multimedia software and system documentations) and a web version (interactive multimedia software, system documentations and samples of use). Online access to the interactive multimedia software was nominated as the best option for its delivery for several reasons, including:

- Advice from teachers and school ICT coordinators at the beginning of the study (analysis phase);
- Inconsistency in availability of hardware and software facilities in various schools;
- Difficulties with software installation on individual computer systems;
- Diverse spread of geographical distance of participant schools’ location;
• Large number of users;
• Access to high speed bandwidth internet in almost every school in Western Australia;
• Accessibility of use through interactive whiteboard, laptop and personal platform at the same time.

A domain (a name to identify a particular web page), host (space on a server) and a secure database system was developed for delivering the interactive multimedia software online. Participants were allocated secure login details (username and password) to access the software and other documentation such as a user guide. Figure 4.14 shows the study branding and website.
Documentation

User documentation is a very important feature of a high-end multimedia system. A user guide (manual) is intended to help users quickly and easily understand the system’s functions. It also includes a brief of the software goals, operation manuals, system requirements, technical support, and development acknowledgments and copyrights permission. User guide documentation was developed for each phase of this study as shown in Figure 4.15 and Appendix G.

Figure 4.15. The user guides documentation, a. Tools 1 user guide, b. Tools 2 user guide

Maintenance

Maintenance involves the management of the operation and use of a product once it has gone into distribution (Sommerville, 2011). Depending on the extent of the work, maintenance activities may be accomplished a new development cycle for planning through authoring and evaluation. After launching the application, the author of this thesis (who also is the designer and developer of the software) was constantly available and accessible (during the trial period) to the participant teachers to assist those who encountered technical and pedagogical problems and to answer questions. Figure 4.16 shows a sample of a teacher’s technical questions, which were resolved by the designer.
The explained IMDLC model, also summarised in Figure 4.17, was used as a basis for the design and development of the two educational interactive multimedia software tools (Tools 1 and Tools 2) of this study (Figure 4.18). The features of these tools are discussed in details in Chapters 5 and 6.
Figure 4.17. Summary of activities in the proposed IMDLC model
4.4. Chapter conclusion

In the absence of a universal methodology for the development of educational interactive multimedia software, this chapter has introduced a new model as a framework, which was used in the development process of the study’s multimedia software tools. The individual phases of the model have been described, with the underpinning the cognitive theory of multimedia learning principles as a guideline.

In the next chapter, the first phase of the research (Phase 1) will be presented with reference to the conceptual framework, instructional design strategy and the interactive multimedia educational software model described in this chapter (IMDLC). It discusses the educational interactive multimedia software’s components and its trial in real world settings. The results and findings of the study with reference to Phase 1 of the study are also presented.
Note for readers:

For accessing the My Maths Story's multimedia software applications (Tools 1 and Tools 2), please visit www.mymathstory.com and contact the author of this thesis.
Chapter 5
MY MATHS STORY, PHASE 1:
IMPLEMENTATION AND FINDINGS

The chapter presents the implementation process and findings of Phase 1. This chapter explores the contribution that an interactive multimedia application can make to teaching and learning by examining how it can best be created and used to enhance meaningful teaching and learning activities based on using children’s literature. Essentially, this chapter is concerned with specifying not only the scope of the My Maths Story interactive application but also the context in which it was used. It describes the series of activities that were undertaken to plan, design and implement the first set of interactive multimedia tools following the guidelines of the ADDIE instructional system design model. Finally, the findings and evaluation of the tools are provided, followed by an account of lessons learnt from Phase 1, which were used to inform the design of Phase 2 (Chapter 6).

5.1. Introduction

This thesis argues that, when it is based on an acceptable approach, the use of multimedia for teaching abstract subjects such as mathematics can provide successful teaching and learning experiences for both teachers and learners. This approach should be based on acceptable pedagogical principles, general human-computer interaction principles as well as educational theory. In short, consideration needs to be given to both the technical
aspects of interactive software design and the pedagogical aspects of integration into the curriculum and teachers’ pedagogical beliefs and practices. Failure to pay attention to how software might be integrated into the curriculum may result in it not being used (Cairncross & Mannion, 2001).

Chapter 2 presented an overview of cognitive learning, mathematics pedagogies and the limitations of many existing mathematics software packages available in Australia. Chapter 3 proposed a new conceptual framework based on Bloom/Anderson’s cognitive learning objectives and using children’s literature for the teaching and learning of mathematics in the primary school. Chapter 3 also explained the requirement for an instructional system design (ISD) as a guideline for the accomplishment of educational objectives and the evaluation of the software tools. It described in detail the components of the ADDIE instructional design model as a systematic approach to analyse teaching and learning needs and the development of tools to meet the identified needs. Chapter 4 proposed a new model for the design and development of interactive multimedia software as an educational tool, based on human-computer interaction and multimedia cognitive learning principles.

Chapter 5 presents the entire implementation process of Phase 1 based on the ADDIE model, taking into account all the mentioned elements. The software was trialled in real world settings as part of this process. The Analysis phase, the first phase of the ADDIE model, is outlined in the following section.

5.2. My Maths Story - Tools 1, the implementation of the ADDIE instructional system design

5.2.1. Analysis

Disconnections between theory for designing educational applications and theory concerned with the application of educational software for teaching in classrooms (Offer & Bos, 2009), coupled with a lack of alignment with curriculum and instruction to support learning (Cairncross & Mannion, 2001, Mumtaz, 2000; Yelland, 2001), have been highlighted as main issues that can hamper the quality and relevance of existing computer based educational applications. To avoid this problem, in the first step of Phase 1, detailed analysis
of the following areas took place within the first phase of the ADDIE model: (a) users’ needs and requirements; (b) target users’ characteristics; (c) pedagogical and learning objectives; and (d) subject matter.

5.2.1.1. Analysis of users’ needs and requirements

The researcher investigated and identified Australian mathematics teachers’ needs and their classroom requirements through a range of activities, including:

- Interviewing and discussing with teachers and mathematics educators about their requirements for designing new software;
- Ascertaining the limitations of existing mathematics software through literature review, teacher interviews and direct observation of use in classrooms;
- The observation of mathematics teaching and learning activities (computer-based and none computer-based) in classrooms;
- The identification and examination of some of the preferred computer-based educational applications used in Australian primary school classrooms;
- The study of mathematics pedagogies in early childhood and primary;
- Review of the Australian Curriculum: mathematics;

Furthermore, the researcher was present in six different early primary years classrooms for four months to observe the interaction of teachers and learners with existing computer-based applications. This approach assisted the researcher in better understanding some of the issues mentioned by teachers in the interview, as well as identifying some other concerns and needs for the design and integration of new mathematics software into the curriculum. For example, it was found that computer narration of instructions in non-Australian accents (British English, American English and non English based countries such as India) causes children some confusion in understanding the instructions, while repeating the same instructions by the teacher in an Australian accent erases the issue. This informed the researcher that this issue needed to be addressed in the new application through the use of a Standard Australian English accent.
These activities helped the researcher (who is not a trained primary teacher) to understand the needs of teachers and children in Australian classrooms in relation to the teaching and learning of mathematics. For example, through conversation and informal interviews with teachers (K-Year 4) and mathematics educators, an understanding relating to the technological and pedagogical limitations associated with using existing applications were identified. An overview of the investigation outcomes is given in Table 5.1.

<table>
<thead>
<tr>
<th>Technological and pedagogical limitations of existing mathematics educational software application identified by teachers (K-Y4) and mathematics educators</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lack of alignment with teachers’ preferred pedagogies</td>
</tr>
<tr>
<td>• Lack of alignment with the Australian Curriculum</td>
</tr>
<tr>
<td>• Inappropriate or incoherent educational theory underpinning software</td>
</tr>
<tr>
<td>• Restricted to one subject area and disconnection between different subject areas</td>
</tr>
<tr>
<td>• Difficult to modify for teaching different concepts at various levels</td>
</tr>
<tr>
<td>• Lack of appeal to children, leading to limited engagement</td>
</tr>
<tr>
<td>• Lack of descriptive feedback to children</td>
</tr>
<tr>
<td>• Too much emphasis on assessment of students’ learning using scores and timing</td>
</tr>
<tr>
<td>• Individual and repetitive based activity (over emphasis on drill and practice)</td>
</tr>
<tr>
<td>• Lack of problem solving and high order thinking activities</td>
</tr>
<tr>
<td>• Imported from overseas (foreign based culture and design elements)</td>
</tr>
<tr>
<td>• Complicated and time consuming to learn the actual technology used in the application</td>
</tr>
<tr>
<td>• Complicated and distracting graphics, animation and background music</td>
</tr>
<tr>
<td>• Slow loading time (in many available online software)</td>
</tr>
<tr>
<td>• Software installation problems</td>
</tr>
<tr>
<td>• Lack of access to software designers and developers for changing small parts of the application to fit classroom needs</td>
</tr>
<tr>
<td>• Lack of access to technological assistance/support</td>
</tr>
<tr>
<td>• Lack of clear and comprehensive instructions and guidelines</td>
</tr>
</tbody>
</table>

Table 5.1. Existing educational software’s technological and pedagogical limitations

Software that teachers can use in classrooms to model, share and discuss a range of mathematical concepts with children, as well as being suitable to be used by children independently or in pairs or small groups, was highlighted as one of the main requirements.
A teacher educator supported this by saying:

“There are a lot of applications out there that are mainly behaviourist, repetitive and quiz based, but there are not so many that are creative or collaborative, which can be integrated in classrooms and sit better to the types of pedagogies of our primary school teachers… teachers are crying for this sort of software… that is the reason they don’t like 95% of applications that are out there.”

As well as identifying problems and difficulties associated with existing software applications, some of their positive features were identified which were then considered for incorporation in the new software. Classroom observations also helped the researcher to consider areas where multimedia might add value in teaching a particular concept. For example, the direct manipulation of multimedia objects in a mathematic activity (such as addition) and posing different questions and allowing children to manipulate, explain and express their mathematics understanding in a quick and easy way were identified as advantages that interactive multimedia software can offer.

Finally, a review of the Australian Curriculum and the study of mathematics pedagogies in early childhood and primary helped the researcher to identify suitable mathematics pedagogies (such as teaching mathematics through storytelling) and objectives of the Australian Curriculum.

5.2.1.2. Analysis of target users’ characteristics

Primary school teachers and children (K to Year 4) were the main target users of this study’s multimedia software. A wide range of prior experience in teaching and using computer-based applications was observed among the participating teachers. Through conversation and informal interviews with junior primary school teachers, the researcher found that participant teachers’ experiences in using computer-based applications and their response, beliefs and acceptance of using a new technology as teaching tools were varied. Many mentioned limitations in existing computer-based applications (Table 5.1) and limited professional development and training were highlighted as main reasons for not using and integrating technology in their classroom teaching. A range of technology skills was evident among participating teachers. Teachers’ technology skills ranged from very
young and comfortable with technology (2 years experience in teaching) to experienced teachers (up to 48 years experience in teaching) who were not very comfortable around technology. An early primary teacher with 41 years experience in teaching responded to a question about the use of computer-based application in her classroom as follows:

“The only things that I do with computer are checking my email, typing and sometimes searching for information…I know I should do more than this, but do not know how.”

A young teacher’s response to the same question was:

“Computer-based applications give me many opportunities to explain and demonstrate a subject in an exciting and interesting way to my class.”

Learners (children), as the second main target users, were not a homogenous group either. However, a great deal of technology skill was not expected from children of such a young age (around 5 to 9 years old), but their attitude towards and acceptance of using technology was more positive. Almost all children in this age range could click, drag and drop an object by mouse or on a touch screen. Their ability to read and write (typing) was varied.

5.2.1.3. Analysis of pedagogical and learning objectives

Clear pedagogical and learning goals and objectives are an essential element of any multimedia application design (Frey & Sutton, 2010; Gagné, Wager, Golas, Keller, & Russell, 2005). Pedagogical objectives could be described as what students will be capable of doing after the lesson or series of lessons or learning experiences (LeLoup & Ponterio, 2003). Goals and objectives need to be specific and align with the curriculum. Number and Algebra, Measurement and Geometry and Statistics and Probability are three content strands in the Australian mathematics curriculum. The first strand, Number and Algebra, contains four sub categories, including: Number and place value; Fractions and decimals; Money and financial mathematics; and Patterns and algebra. The broad learning objective of Phase 1 of this study was to design and develop a multimedia application that teachers could integrate in their classroom to teach the Number and place value substrand of the Australian Curriculum. Details of the Number and place value substrand of the Australian Curriculum (Year 1-Year 3) is summarised in Table 5.2.
<table>
<thead>
<tr>
<th>Year 1 Content Descriptions</th>
<th>Year 2 Content Descriptions</th>
<th>Year 3 Content Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number and Algebra</strong></td>
<td><strong>Number and Algebra</strong></td>
<td><strong>Number and Algebra</strong></td>
</tr>
<tr>
<td>Number and place value</td>
<td>Number and place value</td>
<td>Number and place value</td>
</tr>
<tr>
<td>Develop confidence with number sequences to and from 100 by ones from any starting point. Skip count by twos, fives and tens starting from zero (ACMNA012)</td>
<td>Investigate number sequences, initially those increasing and decreasing by twos, threes, fives and ten from any starting point, then moving to other sequences (ACMNA026)</td>
<td>Investigate the conditions required for a number to be odd or even and identify odd and even numbers (ACMNA051)</td>
</tr>
<tr>
<td>Recognise, model, read, write and order numbers to at least 100. Locate these numbers on a number line (ACMNA013)</td>
<td>Recognise, model, represent and order numbers to at least 1000 (ACMNA027)</td>
<td>Recognise, model, represent and order numbers to at least 10,000 (ACMNA052)</td>
</tr>
<tr>
<td>Count collections to 100 by partitioning numbers using place value (ACMNA014)</td>
<td>Group, partition and regroup collections up to 1000 in hundreds, tens and ones to facilitate more efficient counting (ACMNA028)</td>
<td>Apply place value to partition, rearrange and regroup numbers to at least 10,000 to assist calculations and solve problems (ACMNA053)</td>
</tr>
<tr>
<td>Represent and solve simple addition and subtraction problems using a range of strategies including counting on, partitioning and rearranging parts (ACMNA015)</td>
<td>Explore the connection between addition and subtraction (ACMNA029)</td>
<td>Recognise and explain the connection between addition and subtraction (ACMNA054)</td>
</tr>
<tr>
<td>Solve simple addition and subtraction problems using a range of efficient mental and written strategies (ACMNA030)</td>
<td>Recognise and represent multiplication as repeated addition, groups and arrays (ACMNA031)</td>
<td>Recall addition facts for single-digit numbers and related subtraction facts to develop increasingly efficient mental strategies for computation (ACMNA055)</td>
</tr>
<tr>
<td>Recognise and represent division as grouping into equal sets and solve simple problems using these representations (ACMNA032)</td>
<td>Recognise and represent division as grouping into equal sets and solve simple problems using these representations (ACMNA032)</td>
<td>Recall multiplication facts of two, three, five and ten and related division facts (ACMNA056)</td>
</tr>
</tbody>
</table>
| **Table 5.2. Number and Place Value substrand of the Australian Curriculum (Year 1-Year 3)**


Reinforcing and extending children’s mathematical language and making cross-curricular links with literacy through the application was another important pedagogical objective. A further objective was for children to learn mathematics concepts through the acquisition of knowledge and also the ability to transform that knowledge and apply it critically to new situations through using of the multimedia application. Moreover, the ability to recognise, understand and analyse a mathematics problem through using elements of the story was another objective.

5.2.1.4. Analysis of subject matter

Subject matter analysis defines the content that needs to be included in the teaching and learning process (Anderson, Rourke, Garrison, & Archer, 2001), which is outlined by the pedagogical and learning goals. A component of subject matter analysis is searching for optimal resources. As mentioned in Chapter 2, using children’s literature is an effective approach in mathematics education for young children and was acknowledged (by participants of this study) as an appropriate and accepted teaching method in Australian mathematics classrooms. This was followed by discussions (with teachers and mathematics educators) about sourcing a suitable and appropriate mathematics concept storybook as basis content of the interactive multimedia application so it could be integrated into the teaching and learning environment for reaching pedagogical and learning objectives.

Based on a review of existing mathematics concept books and discussions with teachers and other mathematics educators, an engaging mathematics concept book, “One is a Snail, Ten is a Crab”, a counting by ‘feet’ book written by April Pulley Sayre, Jeff Sayre, and Randy Cecil (2003) was selected. This picture book is about counting animals with various numbers of feet; e.g. “5 is a dog (with 4 feet) and a snail (with 1 foot)”. With permission from the publisher, this book was used as a basis of the multimedia software in Phase 1 (Figure 5.1).

5.2.2. Design

The data from the analysis phase provided important information to support decisions in the design stage. The researcher used this information to identify areas where multimedia might add value in mathematics teaching and learning contexts where traditional methods were unable or less likely to provide.

The proposed conceptual framework (Figure 3.4), which captures all elements of the Bloom/Anderson taxonomy, was used as a guideline in selecting and designing instructional strategies to address the teaching and learning goals and objectives. As explained in the literature review, various instructional strategies for teaching mathematics exist. This study applied a range of instruction strategies to capture all levels of the proposed framework through the use of multimedia technology. The instructional strategies used were: Explicit Teaching and Scaffolded Instruction, Fluency Building (Skill Building) and Problem Solving and Collaborative learning. The multimedia educational tools contained three components, which applied all elements of the selected instructional strategies at different levels of the conceptual framework, including: (1) Interactive Storybook software, (2) Students Activity software; and (3) Group Project software.
A summary of design features and activities is given in Table 5.3. These are explained in the following sections.

<table>
<thead>
<tr>
<th>Instructional strategies</th>
<th>Conceptual framework</th>
<th>Bloom/Anderson taxonomy</th>
<th>Interactive multimedia components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit Teaching and Scaffolded Instruction</td>
<td>Storytelling</td>
<td>Remembering Understanding</td>
<td>Interactive Storybook software</td>
</tr>
<tr>
<td>Skill building</td>
<td>Fluency building (Skill building)</td>
<td>Applying</td>
<td>Students Activity software</td>
</tr>
<tr>
<td>Problem Solving and Collaborative learning</td>
<td>Problem solving</td>
<td>Analysing Evaluating Creating</td>
<td>Group Project software</td>
</tr>
</tbody>
</table>

Table 5.3. Summary of the ADDIE design phase

5.2.2.1. Interactive Storybook software

Storytelling through the use of children’s literature is the first level of the conceptual framework (lower section), where the whole class can be engaged. Teacher involvement in focusing children’s attention on the story, and the embedded mathematical concepts, and the building of mathematics comprehension, is substantial at this level. Through storytelling and the use of elements of the chosen mathematics concept storybook (for example, characters, scenes, numbers, words), the areas where multimedia (such as image, text, sound, audio, animation) can add value in mathematics teaching and learning in engaging ways were identified.

Explicit teaching and scaffolded instruction were used as the main instructional strategies in designing the interactive storybook software component. The first component of this study’s educational tools, Interactive Storybook software, was based on these instructional strategies through explicit teacher modelling and scaffolding instruction.

The “One is a Snail, Ten is a Crab” mathematics storybook is about counting animals with various numbers of feet and each page of the book focuses on particular number. For example, the first number is “1” and a snail (one of the characters of the book) always represent the number 1, because a snail has one foot, while a person with two feet
represents number “2”, whilst number “3” is represented by a person (with two feet) and a
snail (with one foot) (Figure 5.2).

![Figure 5.2. “One is a Snail, Ten is a Crab” book: example of inside pages](image)

The same theme was carried out in the software by presenting and focusing on a particular
number through the use of multimedia technology. In the software, each page of the book
was reflected as an individual screen and focused on introducing a specific number as
well as providing teachers and children with the ability to interact, modify and create a new
story. Various media elements were created to symbolise the particular number (multiple
representations) in each screen, along with the ability for users to create a new mathematics
related story, including:

| Interactive table of contents: | interactive table to find and show the order of different parts of the interactive software as well as individual hyperlinks to navigate users to the different parts of the Interactive Storybook software. |
| Character objects: | interactive picture of the characters (snail, person, dog, insect, spider and crab) to visually represent the content. Users could add, move or erase these interactive objects from the screen. |
| Story reader: | an interactive audio icon to trigger the computer to read the story in a human voice with a familiar accent to the children (Australian accent) on each individual screen. |
| Number: | an interactive icon to present numerical information of a number through animated numeral writing (for example, 1, 2, 3) in a familiar font to children (in this case, Victorian modern cursive script). |
**Text**: an interactive icon to present animated alphabetic writing of a number (for example, one, two, three) in a font familiar to children (in this case, Victorian modern cursive script).

**Sound**: an interactive icon to present a number by presenting a series of sounds to match the number concerned.

**Arrow**: an interactive icon to point characters’ foot/feet.

**Blackboard**: an interactive icon with the ability to type input words through typing (like a blackboard).

**Navigation**: forward and backward icons to allow the user to go back and forth between the screens of the story.

**Home**: an icon with the ability to directly reach the home screen (Table of Contents).

**Clean or Sweep**: the ability to remove objects or clean the screen.

**Pen**: an icon with the ability to write and draw on the screen.

Figure 5.3 illustrates an early stage draft of the Interactive Storybook software’s design strategies with placeholders for the icons.

*Figure 5.3. Illustration of the Interactive Storybook software design strategies*
The design of the Interactive Storybook enables teachers to use it to introduce, model, show or discuss many mathematics concepts related to the “Number and Place value” substrand of the Australian curriculum. For example, the story can be read to children (by the human voice story reader), then teachers can introduce a particular number through multiple representations including visual, numerical, alphabetical and audio. They can also manipulate the story through interactive elements on the software and ask children how, why and what questions. Children also can be active participants in the lesson by answering teachers’ questions through manipulating, adding and removing objects around the screen. For example, in the page with the title of “2 is a person”, multimedia elements can be used to present the number “2” in animated numerical form (by clicking on the Number icon), animated alphabetical form (by clicking on the Text icon), audio form (by clicking on the Sound icon) and visual form (number of objects). It is also possible to clear the screen (by clicking on the Clean icon) and create a new story by adding other characters to the screen.

In the “One is a Snail, Ten is a Crab” storybook, after the number 10 (“10 is a crab”), the numbers begin to skip by 10, so the number after 10 is 20, with the title of “20 is two crabs” and then 30, 40, 50, 60, 70, 80, 90 and 100. In order to present between tenth numbers and after “100”, a blank page with a clean background and all multimedia elements (characters and icons) includes between tens numbers and after number “100”. Through this, teachers can ask children to create their own number stories by adding the animals that their total of feet represents the number. For example, if the focus number is “11” (which is not in the actual storybook), students can make it by dragging and dropping a crab character (with 10 feet) and a snail (with 1 foot) or two dogs (8 feet) and a person (two feet) and a snail (1 foot). They can also choose to use the pen tool (Pen icon) to draw the characters.

5.2.2.2. Student Activity software

The second component of this study’s educational tools, Student Activity software focuses on skill-building through enabling individual students to practise the knowledge and understandings gained through the first level. This component aligns with the middle level of the conceptual framework, which is based on the Apply category of the Bloom/Anderson taxonomy.
The mentioned elements of the story (characters, scenes, numbers, words), media features as well as common mathematical symbols, such as plus (+), subtract (−), multiply (×), divide (÷) and equal (=), were used in the design of the Student Activity software, which encouraged fluency through the skill building strategy (Figure 5.4).

![Sample illustration of the Student Activity software](image)

_Figure 5.4. Sample illustration of the Student Activity software_

Through the elements of the Interactive Storybook software (first component), teachers introduce and demonstrate a specific concept then gradually move students to the second component (Student Activity software) for practising and memorising the taught concepts.
For example, if the learning focus is on skip counting, the teacher can explain and model the concept through the Interactive Storybook by creating different stories about skip counting, describing the scene and showing the concept. After children gain knowledge and understanding of the concept, teachers can use the Student Activity software for student individual practice and skill building. Through interacting, manipulating, and creating stories, students can practise their fluency skills by calculating answers, finding various answers and recalling factual knowledge and concepts readily. Furthermore, students may receive immediate feedback from teachers on their work and increase their learning of specific skills in specific area.

The ability to manipulate activities to an appropriate level of difficulty and move from one level to the next is an important feature of this component of the application. Through this component, teachers can design activities that may look the same in appearance (because they use familiar characters and story themes) but are at different levels of difficulty. Also the ability to use the designed activity by children in different formats such as print, on a personal computer or through an interactive whiteboard is another feature of the Student Activity software.

5.2.2.3. Group Project software

The third component of the tools, named Group Project software, used the problem solving and collaborative learning instructional strategies. This is aligned to the upper level of the conceptual framework, which is based on last three categories (“Analyse”, “Evaluate” and “Create”) of the Bloom/Anderson taxonomy.

This component contains all of the elements of storytelling and multimedia used in the first two software tools (Interactive Storybook software and Student Activity software). However, this component has an extra feature for recording children’s voices while they are solving a maths problem individually, in pairs or small groups. This is a feature to help teachers understand students’ mathematical thinking through their verbalisation and reasoning (thinking aloud) (Brown, Collins, & Newman, 1989) while solving a problem. Teachers can divide the students into pairs or small groups and pose a maths problem (for example, a mathematical word problem) and ask children to find solutions. Children’s conversations,
reasoning and mathematical dialogue during problem solving can be recorded, saved in the computer and teachers can later access this for assessment purposes. The listening ability of children (verbal) and seeing the final solution to the maths problem on their computer or print paper (non verbal) will provide important information to teachers. This information may include, children's thinking and understanding by drawing on their previous knowledge, apply this knowledge toward finding a solution to the problem and detecting misunderstanding and confusion of a particular area during the process. To avoid distraction from students’ performance while working on mathematics problems, the recording feature (microphone), was designed to be outside the working screen. Thus, teachers are able to record the conversation without fear of losing children’s attention from their activities (Figure 5.5).

Furthermore, teachers can use this feature as a presentation tool to share different children’s solutions to a specific mathematics problem to the whole class. Thus, teachers can show, review and explain different ways of solving a problem in a collaborative way and pose “why” and “how” questions to encourage deep understanding of the suggested solution.
In the final stage of the design phase, a formative evaluation was conducted to gain feedback about the selected instructional strategies, multimedia elements and the mathematics content. The designed components were presented to three primary school teachers and two mathematics educators. Different pedagogical strategies (as mentioned above), samples of teaching and learning activities and teachers’ and learners’ contributions were clearly explained during the presentation. Through this process, the tools were submitted to critical judgment and enabled the researcher to move on to the Development phase.

5.2.3. Development

The development phase was based on the results of the analysis and design phase. The development process of this study’s educational interactive multimedia software was based on the Interactive Multimedia Development Life Cycle (IMDLC) model, as explained in Chapter 4. Through the structured process of this model (planning and conceptualisation, design and prototyping, production, testing and evaluation, deployment and maintenance) the operational functionality, graphical elements, software interface, media production and testing of the software were established. The components of the educational tools, including the Interactive Storybook software, Students Activity software and Group Project software, which were designed in the previous step, were created through the steps of the IMDLC model in this (development) phase.

Figure 5.6 shows the interactive multimedia software development process. The information from the analysis phase of the ADDIE (section 5.2.1 of this chapter) was used for the Planning and Conceptualisation stage of the software development (Figure 5.6a). The outcomes from the planning and conceptualisation stage and information from the design phase (section 5.2.2) informed the IMDLC’s Design and Prototyping stage. Clark and Mayer six principles of multimedia learning design (as discussed in Chapter 2) were considered and applied at this stage. Figures 5.6b illustrates some graphical design activities conducted in the design and prototyping stage. At the end of this stage, a miniature version of the final product was prepared (with limited functionality) for a formative evaluation (Alpha testing). Different design elements (for example, icons, navigation, storyboard, flowchart), their functionality and examples of use in teaching
and learning were explained and demonstrated to three primary school teachers and
mathematics educators (the same people involved in the design phase evaluation).
One area that was evaluated was whether the abstract symbols such as icons clearly
represented their meaning to users. Another area was whether it was possible to easily
access different part of software (the navigation system) without getting lost. This
evaluation was also helpful for assurance as to whether the designed multimedia features
captured the selected teaching strategies as discussed in section 5.2.2. Feedback
from these participants informed the researcher to make the changes in both graphical
appearance and pedagogical features of the tools before the production phase.

The **Production** stage of the IMDLC model followed the map provided by the design and
prototype stage. Graphic production, media production, and software programming were
conducted to produce graphical and media elements in digital formats. Source code was
written to make the system interactive and functional (Figure 5.6c). Before the final release
of the tools, Beta testing was conducted by distributing the tools to two junior primary
school children and four K-Year 4 primary school teachers for daily use over a period of
two weeks. Some content mistakes and usability problems were detected through the
Beta testing. For example, children had some difficulty to use the Pen icon and teachers
noticed difficulty in moving from some pages to the Table of Content page. These issues
were resolved before the final release of the tools (Figure 5.6d).

The **Deployment** stage of the IMDLC was based on the user requirements analysis
and media delivery advice (as discussed in Chapter 4). The final developed product (all
components of the interactive multimedia software) was delivered through an online
system (Figure 5.6e). A user guide (manual) was developed and linked to the Interactive
Storybook software to provide help to user. Other types of media delivery such as print
and CD/DVD were created during this stage.
Figure 5.6. Development phase, based on the IMDLC model: a. planning and conceptualisation, b. design and prototyping, c. production, d. testing and evaluation, e. deployment and maintenance
5.2.3.1. Formative evaluation

A substantial formative evaluation was conducted after executing the development phase and before implementation of the software in schools. For this purpose, the developed tools were presented to 32 pre-service teachers and 2 early primary mathematics educators. Each pre-service teacher and mathematics educators assessed different parts of the application for approximately 25 minutes (Figure 5.7). Through this process, 24 pre-service teachers and early primary mathematics educators’ comments and suggestions were collected via questionnaire (see Appendix B2).

Through this evaluation process, some technical issues were detected, for example the “Sweep” (Clear) button did not remove all objects in some pages and one link in the Table of Contents was not functional. As well as identifying software bugs (glitches), pre-service teachers suggested some modifications to some of the software element. Table 5.4 lists some of the pre-service teachers’ and mathematics educators’ comments and suggestions. Table 5.5 shows a summary of their responses to some of the technical and pedagogical features of the application.
Table 5.4. Pre-service teachers’ and early primary mathematics educators’ suggestions and comments

<table>
<thead>
<tr>
<th>Suggestions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “There appear to be a shadow in some pictures.”</td>
</tr>
<tr>
<td>• “It might be better to make the numerical animation slightly slower.”</td>
</tr>
<tr>
<td>• “Only a couple of pictures are a bit pixelated.”</td>
</tr>
<tr>
<td>• “It would be good to have a “replay” button for each numeric and alphabetic animation.”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• “Great to see the writing to the style used in WA [Western Australia] schools.”</td>
</tr>
<tr>
<td>• “It is simple and easy to use and the program allows teacher to modify and create as many example as they need.”</td>
</tr>
<tr>
<td>• “Very simple and easy to use for teachers and children…very engaging!”</td>
</tr>
<tr>
<td>• “The software can be used for various concepts such as multiplication, subtraction, addition… love that the software also provided a blank page so teacher and children can create their own number story or word problem.”</td>
</tr>
<tr>
<td>• “I like the different options of using media, audio, visual, icon design… I can see teachers can do so many things in their class through this software.”</td>
</tr>
<tr>
<td>• “It generated a very engaging learning atmosphere; children would love to be able to listen to the story as well as manipulate and create their own mathematics story.”</td>
</tr>
<tr>
<td>• “It is a great teaching tool for the classroom, which has interactive whiteboard.”</td>
</tr>
</tbody>
</table>
### Technical features of the My Maths Story software, Tools 1

<table>
<thead>
<tr>
<th>Rating (%)</th>
<th>A. Strongly disagree, B. Disagree, C. Undecided, D. Agree, E. Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>The software has a professional look/presentation.</td>
<td>25%</td>
</tr>
<tr>
<td>The screens are well-structured and the design is clear.</td>
<td>25%</td>
</tr>
<tr>
<td>Menu, graphic, animation, audio and the general layout interface are consistent.</td>
<td>42%</td>
</tr>
<tr>
<td>It is easy to navigate through the application.</td>
<td>25%</td>
</tr>
<tr>
<td>Multimedia elements are easy to find and use.</td>
<td>34%</td>
</tr>
<tr>
<td>The application is enjoyable to use.</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Pedagogical features of the My Maths Story software, Tools 1

<table>
<thead>
<tr>
<th>Rating (%)</th>
<th>A. Strongly disagree, B. Disagree, C. Undecided, D. Agree, E. Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Through the use of this application, learning mathematics concepts could be more enjoyable, engaging and motivating for children than when using other resources.</td>
<td>42%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain and demonstrate mathematical concepts.</td>
<td>25%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain ‘why and how’ questions relating to the mathematics concepts being taught.</td>
<td>42%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could facilitate collaborative learning.</td>
<td>42%</td>
</tr>
<tr>
<td>Young students (Years 1 to 4) could navigate the software.</td>
<td>17%</td>
</tr>
<tr>
<td>It would be easy for student to create a simple mathematics concept story through the use of this application.</td>
<td>34%</td>
</tr>
<tr>
<td>Through the use of this application, students could practise number facts.</td>
<td>34%</td>
</tr>
<tr>
<td>Student could use this application individually or in pairs to analyse, explain and solve a mathematics problem.</td>
<td>25%</td>
</tr>
</tbody>
</table>

Table 5.5. Pre-service teachers’ responses to some questions about technical and pedagogical features of Tools 1
The survey and interview data were analysed and the necessary changes were introduced to improve the tools. Once this process was finalised, the tools were considered ready to move to the Implementation phase.

5.2.4. Implementation

In order to demonstrate the utility of the tools in facilitating mathematics teaching and learning, the tools were offered to five different primary schools in Western Australia. Three public, one private and one specialist school for English as Second Language students, from areas with different social and economic demographics, trialled the tools for approximately two school terms in 2012. Twelve teachers and 284 students in multiple grade levels (K to Year 4) used the tools in their classrooms for the teaching and learning a range of mathematical concepts. The software tools’ components were used in classrooms (on interactive whiteboards) for whole class lessons and in school computer labs (on personal computer and laptops) for individual and small group work.

Participant teachers used the different components of the application for teaching counting, place value, number sense, number relationships and basic addition to younger children (K-Year 1), while they used it to teach skip counting, counting by sets of 2’s, 4’s, 10’s, even and odd numbers, addition, subtraction and multiplication in different ways for older children (Year 2-Year 4) throughout the two school terms. Teachers created various interactive stories by choosing scenes, characters (for example, a snail, person, dog, insect, spider, crab) and multimedia elements such as sound and text (Figure 5.8). They taught the intended learning outcomes or objectives by explaining the scene, retelling, and asking ‘why’ and ‘how’ questions. This helped students to recall facts, terms and concepts by remembering, describing and explaining (the “Remember” and “Understand” categories of the Bloom/Anderson model-lower level of the conceptual framework).
Through interacting, manipulating, and creating various stories, students practised their fluency skills by calculating answers, finding answers to maths problem and recalling factual knowledge and concepts readily (the “Apply” category of the Bloom/Anderson model and middle section of the conceptual framework) (Figure 5.9). Teachers also used the Student Activity software to create mathematics activities for their students in both interactive and print formats. Some examples are presented in Figure 5.10.
Figure 5.10. Some examples of activities created in the Student Activity software

The software was also used for more complex concepts, through teachers generating a story or a mathematics word problem and asking students to analyse, explain and solve the problem, either individually, in pairs or in small groups (the “Analyse”, “Evaluate” and “Create” categories of the Bloom/Anderson model – upper level of the conceptual framework) (Figures 5.11a and 5.11b).
Figure 5.11. a. Student using the tools in pairs or small groups, b. a sample of mathematics world problem created in the Group Project software
The researcher was available and accessible to participant teachers for technical and pedagogical issues and questions during the implementation stage. The researcher was present in classrooms as a non-participant observer throughout the school terms. During each observation session, the systematic observation form was completed to record the use and interaction of teachers and learners with the tools.

Towards end of the school term, individual and semi-structured interviews with the participant teachers occurred. Teachers were also asked to complete a questionnaire. All of the data collection methods were explained and justified in Chapter 3.

5.2.5. Evaluation and Findings

At the end of implementation phase, all data and information, which was collected through semi-structured interviews, questionnaires and observations, were saved and stored in a filing system for processing in the evaluation phase.

5.2.5.1. Technological evaluation

Interview and questionnaire results indicated that teachers were satisfied with the technical aspects of the software. They responded that the design elements and layout design were clean, simple, consistent and well structured.

“I think the look and presentation is very professional and all my students found it very easy to use” Year 3 teacher.

“Love the simplicity and look of the software, very engaging for students” Year 1 teacher.

“Like the clean layout structure of the software and available features, it is interactive and engaging” Year 2 teacher.

Teachers thought that it had been possible to present multiple representations of mathematics concepts creatively and clearly through the use of the multimedia components in the application. All participant teachers endorsed the flexibility of changing and modifying the software to address a range of mathematics topics and to fit their students’ diverse needs.
"It [the software] is very flexible and open-ended, it can cater for many different skill levels in a classroom" Year 4 teacher.

A number of advantages of the software application were highlighted by participant teachers, including: easy to find and use multimedia elements, the ability to change and modify mathematics exercises to suit students’ skill levels, visual and graphical appeal (to children), and the ability to use it with an interactive whiteboard for whole class engagement, as well as its suitability for use individually, in pairs or in small groups.

“...In our school we are using the … (software name) software as our mathematics resource which is based on individual learning, mainly assessment based, and children learn through trial and error. However, I found the My Maths Story software is very flexible… because of the characters and story theme, you can create and tell a story and it makes sense to children. There is a big difference between these two type of applications; it [My Maths Story software] is not just trial and error, right and wrong… I can share ideas with my whole class, my students can use it individually and we can create a small group activity and work as pairs on a problem” Year 3 teacher.

Table 5.6 shows participant teachers’ responses to some of the technical features of the software. However, teachers requested some new features for the development of future the application (Phase 2 tools), which are listed in Table 5.7.

<table>
<thead>
<tr>
<th>Technical features of the My Maths Story software, Tools 1</th>
<th>Rating (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>The software has a professional look/presentation.</td>
<td>12%</td>
</tr>
<tr>
<td>The screens are well-structured and the design is clear.</td>
<td>38%</td>
</tr>
<tr>
<td>Menu, graphic, animation, audio and the general layout interface are consistent.</td>
<td>12%</td>
</tr>
<tr>
<td>It is easy to navigate through the application.</td>
<td>25%</td>
</tr>
<tr>
<td>Multimedia elements are easy to find and use.</td>
<td>36%</td>
</tr>
<tr>
<td>The application is enjoyable to use.</td>
<td>12%</td>
</tr>
</tbody>
</table>

Table 5.6. Participant teachers’ responses to some questions about technical features of Tools 1
### Technological changes and requests

- Ability to move the text box around the screen or remove it from the screen by dragging it to the “Sweep” button
- Ability to expand the text box in the Student Activity software
- Ability to change some of the story elements’ size (enlarging and minimising)
- Add Eraser button in the software
- Add numeric and alphabetic writing of numbers in some screens of the Interactive Storybook software (for example, number 1-100)
- Add mathematics signs (such as +, -, and \( \times \)) in some screens of the Interactive Storybook software

Table 5.7. Participant teachers’ requests for changes or the addition of new features

### 5.2.5.2. Pedagogical evaluation

In response to questions about their pedagogical beliefs and the teaching activities facilitated through the use of the application, teachers stated that they were able to use the software to demonstrate and explain targeted mathematical concepts to their classroom. They indicated that the presentation of mathematics concepts within a story in a multimodal way, and having a chance to choose pictures, audio and animation to tell the mathematics concept story, helped them to express various mathematics concepts much easier and faster than in traditional ways.

“This application has numerous uses for both teachers and students to generate [mathematics] ideas” Year 2 teacher.

“Interactive and engaging way of introducing and explaining mathematics concepts” Year 1 teacher.

“Some of my children have been struggling to memories basic addition facts, for example, 6 and 4 always make 10… it was a really nice way to explain the concept through presentation of picture of an insect with six feet and dog with four feet… seeing the characters of the story visually helped them to memories the facts in
an engaging and fast way whereas in the past, I usually sang a song or wrote over and over the fact with numbers and mathematic signs… I am going to use the software for explaining and modelling subtraction – the take away concept - next week” Year 2 teacher.

“Victorian modern cursive script handwriting is very hard for children to learn in early primary years… using the software to show children visually, the slow animation of the script as many time as children need, was a great way of teaching them the numeric and alphabetic writing” Year 1 teacher.

All participant teachers indicated that listening to narrations featuring a child’s voice with Australian English pronunciation was an effective means of gaining children’s attention. For example, a Year 1 teacher explained:

“Reading the story by an Australian child was the novel and interesting element in the software. Children noticed that it is a voice that they can relate to and another child reading to them, not an adult like a mum or a teacher… children in my class love this aspect of the program.”

Using children’s literature to explain the abstract concepts of mathematics were also specified as advantages of using the application.

“Number are abstract, that’s why children find it hard, but the story’s characters like the snail, dog, spider are real…they can see it in their real life and connect with them straight away” Year 2 teacher.

“Fun and engaging. Students don’t realise that they are doing maths!” Kindergarten teacher.

Participant teachers reported that their students showed increased comfort levels in talking about their understandings of mathematics concepts through making their own stories and sharing and discussing them in the classroom. Memorising and practising a mathematics fact and helping children’s skill building through motivation of using the story’s characters were mentioned as benefits of using the tools.
“I found, it [the software] helps my children to memorise number facts…. It was fascinating for me to see… (student name) working on basic number facts on her computer. I asked her to make “number 16” and she dragged and dropped a crab and an insect, then I asked her to make the same number in another way but do not use the crab… she quickly grabbed two spiders and said, ‘Here are two groups of eight that make 16’. It was fascinating to see her doing and reasoning like that … in the past, she had trouble in this area… it seems to me she was engaged in the story and memorised facts through using the story’s characters” Year 1 teacher.

Modifying the original story by changing characters or settings, explaining the scenes, retelling the story, and asking ‘why’ and ‘how’ questions through variations of the story were highlighted as benefits of using the application in the classroom. Opportunities to interact with the familiar characters from the story in order to create mathematics exercises for various levels, and even for students to pose their own problems and find answers individually, in pairs or in small groups, were revealed as advantages of using the application.

“This week, I opened the software in the interactive whiteboard almost every morning. I created a maths problem, something as simple as “make number 19.” When my children came to the class, first they asked, ‘What is this?’ and then they said, ‘Can we do it?’ I let them play and come up with different ways of making number 19 through using the story’s characters and counting feet… While they were doing this, I asked them to talk and verbalise the process and explain what they were doing to the class. Sometimes I stopped them and posed a question…. The next day, I made the problem a bit harder…” Year 2 teacher.

“A fantastic tool, which provides students with another way of working through operations in a fun and engaging way” Year 2 teacher.

A substantial agreement (100%) was seen among the participant in-service teachers and pre-service teachers in response to the question as to whether they would in the future use the software instead or alongside traditional books in their classroom (Table 5.8). However, teachers suggested variations to the software, as summarised in Table 5.9.
Pedagogical features of the My Maths Story software, Tools 1

<table>
<thead>
<tr>
<th>Pedagogical feature</th>
<th>Rating (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through the use of this application, learning mathematics concepts could be more enjoyable, engaging and motivating for children than when using other resources.</td>
<td>12% 88%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain and demonstrate mathematical concepts.</td>
<td>25% 75%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain ‘why and how’ questions relating to the mathematics concepts being taught.</td>
<td>8% 26% 66%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could facilitate collaborative learning.</td>
<td>12% 88%</td>
</tr>
<tr>
<td>Young students (Years 1 to 4) could navigate the software.</td>
<td>10% 90%</td>
</tr>
<tr>
<td>It would be easy for student to create a simple mathematics concept story through the use of this application.</td>
<td>12% 88%</td>
</tr>
<tr>
<td>Through the use of this application, students could practise number facts.</td>
<td>12% 88%</td>
</tr>
<tr>
<td>If you could choose, would you use this software and the teaching aids in your classroom?</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 5.8. Participant teachers’ responses to some questions about pedagogical features of Tools 1

Pedagogical feature requests

- Hands on (concrete) material based on the story’s character and themes
- Alignment with more strands of the Australian Curriculum
- Story that connects to children’s life in Australia
- Include familiar characters and elements of Australian culture
- Include more mathematics language
- Increase the number of characters, elements and story plots

Table 5.9. Participant teachers’ pedagogical feature requests
5.2.5.3. Observation findings

Observations from the evaluation also indicated that teachers and children tended to work through the application easily and completed tasks relevant to their needs. However, technological problems related to the available ICT technologies in some schools were noted. These caused some difficulties for the users. For example, the interactive whiteboard was not functioning correctly or there was a sound system problem (speakers) that cut the audio narration. One teacher stated: “We had some difficulty in using the application on a few of our computers in the lab due to the old technology used on these computers [out date version of browser and missing sound system]; however, the software works fine on the other computers in the lab and on the interactive whiteboard”.

Furthermore, the observations revealed that children also spent time evaluating the interface elements (such as buttons, icons, background images and animations) as well as learning from the application. This suggests that some children were making an attempt to engage with the material. In the observation of a Year 2 class in their first session of using the software, the class teacher stated:

“Today was the first time that my children saw and used the software and, as you may have noticed, they have gone through the different elements very smoothly and easily… there have been a few places that I was not sure how to operate but the children told me what to do [teacher laughing]… It is a very engaging tool and motivates them to find answers by using the story’s characters.”

Observations of the pairs revealed that children spent time discussing the content of the application as well as time discussing what to do. In particular, children working together appeared to discuss their own mathematics reasoning to solve a maths problems for the story’s characters.

The analysis of observational data indicated that many participant teachers preferred to verbally question or email the researcher about uncertainties regarding how to use a feature or technological concern instead of referring to the software “Help Manual”, which is linked to the application. The participant teachers reported that having training sessions and access to the software developer to request changes to small parts of the application to
suit the classroom needs, was one of the advantage of using this multimedia application.

Through the observations and answering teachers' queries, the researcher found that some of the participant teachers needed to be reminded about several available features in the software. For example, the “microphone” feature in the Group Project software was mentioned as useful feature for recording children's conversations and detecting their mental thinking while solving a mathematics problem (assessment). However, few teachers used this feature.

The student feedback form also indicated that most children were engaged in the story’s mathematics concepts and could apply the concept to different situations. For example, in a student feedback form (Figure 5.12), the student wrote the reason that she liked the program. In the scoring section of the feedback form (highlighted in red circle), she used the story’s characters for giving the software a score (a person and a spider that make 10 for her score). A year 2 teacher also mentioned:

"We were talking about tens in our class other day without mentioning or using the My Maths Story software; however, when I said, ‘Two 10s make 20’, one of my children said, ‘Which is two crabs.’… It was good to realise that they remember the story's mathematics concepts and can apply it to other situations”.

Figure 5.12. A student feedback form
5.3. Discussion and summary

Phase 1 of the study aimed to examine the proposed conceptual framework, the usefulness of the instructional system design model, as well as the practicality of the proposed interactive multimedia model for the development of interactive multimedia software as educational tools to support teachers' and students’ needs in primary school mathematics classrooms.

The findings indicate that teachers were able to use the multimedia application as teaching tools to teach planned objectives such as counting, place value, number sense and addition. Furthermore, the application offered teachers multiple opportunities for modelling, sharing and discussing a range of mathematics concepts within a story in a multimodal way, and helped them to express various mathematics concepts to children in more engaging and faster ways than in traditional way. Also, the findings indicated that the software can help to activate students’ curiosity about a mathematics topic, to engage them in the learning process, to interact with content, to probe critical thinking skills, to keep them on task, to provoke sustained and useful classroom interaction, and, in general, to enable and enhance their learning of subject content individually and in pairs.

The ADDIE instructional design model was found as to be a useful guideline for reaching the teaching and learning needs. Ongoing formative evaluation during the various phases of the model informed the researcher as to whether teachers and students would use the software product and how it should be improved before implementation in real world settings.

The proposed IMDLC model for the design and development of interactive multimedia software, which was underpinned by Clark and Mayer’s (2011) cognitive theory of multimedia learning principles, was found to be suitable for the development process of the educational multimedia software. Phase 1 also served as a pilot for the research process and data collection instruments. All necessary adjustments and refinements were made to the instruments for use in Phase 2.
5.4. Chapter conclusion

This chapter presented the implementation process and findings of Phase 1. Findings revealed that the My Maths Story - Tools 1 application appeared to hold considerable potential for teaching mathematics in primary mathematics classrooms through storytelling and the use of multimedia technology to present multiple representations. The application did not share the limitations of existing mathematics software packages. Nonetheless, teachers requested some new features, which directed this research towards the development of a more complex and dynamic environment in Phase 2.

Chapter 6 presents Phase 2 of the study, which was based on the findings and experiences gained on Phase 1.
Chapter 6
MY MATHS STORY, PHASE 2:
IMPLEMENTATION AND FINDINGS

The previous chapter presented the process of implementation and evaluation of Phase 1. The findings from the Phase 1 informed Phase 2. This chapter first reviews the key findings of the Phase 1, then presents the process of design, development and implementation of the second set of interactive multimedia tools (Tools 2) through a second cycle of the ADDIE instructional system design model. Finally, the chapter concludes with the evaluation results and Phase 2 findings.

6.1. Summary of findings and experiences from Phase 1

The findings from Phase 1 revealed some important technological and pedagogical directions for creating and using a multimedia educational application for the primary mathematics classroom. Phase 1 also intended to examine the usefulness of applying the ADDIE framework and the IMDLC model, as well as to pilot the process of research and the data collection instruments. These findings and understandings, and actions taken to address them in Phase 2, are summarised in Table 6.1.
The ADDIE instructional model proved to be a useful framework for the processes of development of the educational application. Thus, in Phase 2, another iteration of the ADDIE model (as shown in Figure 3.8) was used. The final stage (evaluation) of the ADDIE model, in Phase 1, revealed where revisions were required in each of the other four components of the ADDIE in the Phase 2. The following sections of this chapter explain various activities that were conducted during the different phases of the ADDIE model in Phase 2.

<table>
<thead>
<tr>
<th>Methods/Tools</th>
<th>Findings from Phase 1</th>
<th>Actions for Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ADDIE framework</td>
<td>The ADDIE instructional model proved to be a useful framework for the processes of development of the educational application</td>
<td>Reiteration of the framework cycle (analysis, design, development, implementation and evaluation)</td>
</tr>
<tr>
<td>Tools 1’s technological and pedagogical evaluation</td>
<td>Technological evaluation (see section 5.2.5.1)</td>
<td>A number of technological and pedagogical modifications as mentioned in Table 5.7 and Table 5.9 were required</td>
</tr>
<tr>
<td>The IMDLC model</td>
<td>The IMDLC model was found to be suitable for the development process of the educational multimedia software system</td>
<td>Apply the IMDLC model in the design and development process of the Tools 2</td>
</tr>
<tr>
<td>Data collection methods and instruments</td>
<td>Amendment needed for some questions in the questionnaire and semi-structured interview</td>
<td>Remove some repetitive questions in the questionnaire</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce the number of questions in the semi-structured interview</td>
</tr>
</tbody>
</table>

Table 6.1. Summary of findings and experiences from Phase 1 and actions for Phase 2

The findings indicated that the first set of My Maths Story applications in mathematics classrooms were seen by participating teachers to be useful teaching and learning tools. However (as described in Chapter 5), some technological and pedagogical limitations were highlighted, which needed to be considered and addressed in the second multimedia application.
6.2. My Maths Story – Tools 2, the implementation of the ADDIE instructional system design

6.2.1. Analysis

Analysis of users’ needs and requirements, analysis of target users’ characteristics, analysis of pedagogical and learning objectives, and analysis of subject matter were four components which were considered in the analysis phase of the ADDIE in Phase 1. Except for the analysis of target users’ characteristics (as the target users were the same as the first study), all other components were reviewed in the Analysis stage for Phase 2.

6.2.1.1. Analysis of users’ needs and requirements

Phase 1 participant teachers specified some new requirements (pedagogical and technological) that needed to be considered in Tools 2, including:

- Alignment with more strands of the Australian Curriculum (for example, whole strands of Number and Algebra);
- Use of a story that connected to children’s real life in Australia;
- Use of familiar characters and elements of Australian culture (an Australian based story which contained Australian nature, culture and references to Australian children’s everyday life);
- Use of more mathematics language in the tools;
- Increase in the number of characters, elements and story plots;
- Provision of hands on (concrete) material based on the story’s characters and themes;
- Provision of the ability to move the text box around the screen or remove it from screen by dragging it to the “Sweep” button;
- Provision of an expandable text box in the Student Activity software;
- Provision of the ability to change some of the story elements’ size (enlarging and minimising);
• Addition of Eraser button to the software;

• Addition of numeric and alphabetic writing of numbers in some pages (for example, numbers 1-100);

• Addition of mathematics symbols (such as +, - and x) in some pages of the interactive story.

Teachers’ initial requirements analysis (as discussed in Chapter 5), along with the above mentioned requirements, were addressed in the different stages of the ADDIE instructional system in Phase 2 to meet the teaching and learning needs of the users.

6.2.1.2. Analysis of pedagogical and learning objectives

One of the main needs indicated by teachers in Phase 1 was to develop an educational application that addressed more substrands of the Number and Algebra strand of the Australian Curriculum. To cover this, all substrands of the Number and Algebra strands of the Australian Curriculum were used as pedagogical and learning objectives in Phase 2. These included: Number and place value, Fractions and decimals, Money and financial mathematics, and Patterns and algebra. Thus, teachers were able to define and set a wide variety of mathematics pedagogical and learning objectives that aligned with the Number and Algebra strand in the curriculum and use the multimedia application as teaching tools for achieving the learning objectives such as: place value, Australian finance and money, and fraction and pattern. Details of the Number and Algebra strand of the Australian Curriculum are summarised in Appendix H.

6.2.1.3. Analysis of subject matter

Using an Australian storybook, which was based on Australian nature, culture and children’s everyday life was another suggestion by participant teachers in Phase 1. In discussions with teachers and mathematics educators, and through a review of existing Australian based storybooks, it became apparent that there was no Australian mathematics concept storybook in existence that covered the needs of this study. In the absence of an appropriate Australian maths concept storybook as a basis for the second interactive multimedia software, the researcher decided to create a new one. The researcher wrote and illustrated a
new storybook based on Australian nature and culture with a strong mathematics influence for reaching the pedagogical and learning objectives. The new mathematics storybook was named “Count on Me! A Mathematics Adventure Story”\textsuperscript{1}. The next section explains the content of and the process of writing and editing this new Australian mathematics storybook.

The process of writing: Count on Me! A Mathematics Adventure Storybook

According to Green (2004), “Story is a powerful structure for organising and transmitting information, and for creating meaning in our lives and environments” (p. 1). He also stated: “What is a story? In essence, a narrative account requires a story that raises unanswered questions or unresolved conflicts; characters may encounter and then resolve a crisis or crises. A story line with a beginning, middle and end, is identifiable” (Green, 2004, p. 1). Communicating information in a “memorable form” and “shaping the hearer’s feelings about the information being communicated” have been identified the great power of stories (Zazkis, 2009, p. 3).

It is also stated by Wilburne et al., (2011), that there are some general elements that all good stories have, including:

- **Plot**: good storybooks contain well-developed plots that are interesting, engaging and logical.

- **Setting**: the location of where events take place is an integral part of the story. Writers often included descriptors to help readers identify with the setting. Setting that are authentic, accurate, and interesting are well loved by readers.

- **Characterisation**: good characters are memorable for young readers because the writer creates descriptions about them. Well defined characters, whether human or animals, are presented in a way that enables readers to connect to character’s personality traits and to talk about what they like or dislike about the character.

- **Theme**: the underlying message of the story is understood as its theme. The theme is an integral feature of the story but should not overshadow the story in any way.

\textsuperscript{1} COUNT ON ME! A MATHEMATICS ADVENTURE STORY. Text and Illustrations copyright © 2012 Nasrin Moradmand.
• **Style**: a good storybook is rich in language and description that are a natural part of the story. The language that is employed in a well-written storybook is vivid, evokes rich images of the actions, and reflects the mood of characters and overall story.

(Wilburne et al., 2011, p. 19-20)

Keeping in mind the mentioned elements of story and Australian mathematics curriculum, culture, nature and children’s everyday lives, the researcher introduced a storybook that communicated its message through both illustrations and words. It considered the story components as a means of reaching the goals of teaching and learning mathematics through engaging and familiar characters, objects and children’s real life experiences.

“Count on Me! A Mathematics Adventure Story” is a story of a girl called Hannah, who lives in a small country town (a village) in Western Australia. The story starts by introducing the main character (the girl) and the location where the events take place (the village). The story then presents the other characters (a farmer, a baker, a shopkeeper and a carpenter) and the different settings (such as a farm, a bakery, a shop and a carpentry). After introducing the village and story’s characters, the main character (Hannah), while visiting different places in the village (farm, shop, bakery and carpentry), faces some mathematics problems and tries to solve them. For example, she needs to collect a number of eggs, and some fruit and vegetable from the farm, which requires her to perform counting and number calculations. Figure 6.1 presents the cover and some inside pages of the “Count on Me!” book.
Figure 6.1. The cover and some example of inside pages of the “Count on Me!” book
After writing the initial draft of the book’s script and doing sample drawings of the characters and story plots, the book was given to four primary school teachers (K-Year 4) and two mathematics educators for review and feedback. Through this process, the story concept, theme, setting, plot and characters was found to satisfy the teachers and educators. However, some content errors were detected and revision to some mathematics vocabulary was requested (Figure 6.2).

“Very interesting story, bright, creative and colourful... relates maths skills to real life situation” (Year 1 teacher).

“The idea of story is great and the maths concept is very relevant to my student in the Year 2/3 level. It is great to see the concepts of money, pattern, fraction and grouping in the same story. I think, it would be very motivational for students to read the story and work on the computer, particularly if they be able to create a new story and do different activities” (Year 2/3 teacher).

“Another fantastic book written for young students. It is very related to the Australian Curriculum. The Australian money and finance is presented in a very engaging way in the book” (Year 4 teacher).

Figure 6.2. Sample feedback for revision of the “Count on Me!” book
The teachers’ review also suggested the inclusion of some new concepts in the storybook such as concepts of time (clock) and concepts of location/distance (basic map).

“...just an idea, you could add a clock to each page, so students could work out what time Hannah went to bakery, etc.”.

“At my level, we talk about concepts of map and location... the “Count on Me!” story is a real life story and, in the real world, we are always dealing with location, distances and maps... so it would be great to include a basic map of the village in the story”.

To address these requests, the researcher included the concept of time through adding an analogue clock illustration on several pages of the storybook. The times showing on the clock were changed as the story move forward. A simple map of the village was also added at the beginning of the story to enable children to learn about finding the location and cardinal direction (North, East, South and West) of different places in the village.

After modification and including the reviewers’ suggestions, another version of the book was presented to the teachers and mathematics educators. Printed copies of the book were handed to two primary teachers for reading to children in their classrooms to obtain students’ feedback.

Teachers indicated that the children been engaged in the story and made connections to the story theme, characters and mathematics concepts.

“When I read the story, they [students] were engaged and interested. Students liked the maths problems and enjoyed solving them and helping the hero character...”

Through these processes, the final version of the “Count on Me!” storybook was produced. The completed version of the storybook is presented in Appendix I.
6.2.2. Design

The outcomes of Phase 1 indicated that the instructional strategies applied (Explicit Teaching and Scaffolded Instruction, Skill Building and Problem Solving and Collaborative learning) to capture all levels of the conceptual framework were useful. The three software components (Interactive Storybook software, Students Activity software; and Group Project software) were also noted to be useful in the teaching and learning process. Thus, these strategies and software components were retained, although teachers’ additional requirements were incorporated in the software components.

6.2.2.1. Interactive Storybook software

The “Count on Me!” mathematics storybook focuses on various mathematics concepts throughout the story. For instance, in the farm, the story highlights the use of number and place value; in the shop, attention is on Australian money and finance. Patterns and shapes concepts are emphasised in the carpentry setting, while fractions and decimals are covered in the bakery shop. The story also considers the measurement and geometry concepts by introducing the village map (location and transformation) and a clock (using units of measurement and relationship between units).

Similar to the Tools 1, each page of the book was reflected as an individual screen and focused on introducing the story’s characters and settings (the first few pages of the book) and then revealed various mathematics problems at different points in the story. The media elements that were used in the Tools 1 were applied to the software, along with some new media elements. Table 6.2 illustrates teachers’ requests regarding the new media.
### Requirements

<table>
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<tr>
<th>Requirements</th>
<th>Solutions</th>
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| Ability to change some of the story elements’ size (enlarging and minimising) | Introduced transforming tool icons:  
- Scale up: by drag and rollover an object (shape) over this icon, the object size will enlarge
- Scale down: by drag and rollover an object (shape) over this icon, the object size will reduce |
| Add Eraser button in the software                                         | Introduced Eraser icon: erase hand-drawn lines (by Pen tool)                                |
| Have an expandable text box in the Student Activity software              | Introduced new function to the Blackboard icon: by clicking on this icon, a text box will be made that the user can type in and move around the screen |
| The ability to remove the text box from screen                            | Added new function to allow user to remove text box from the screen by dragging to “Sweep” button |
| Add numeric and alphabetic writing of numbers in some pages (for example numbers between 1-100) | Introduced Number words: ability to drag and drop the numeral writing between One to Hundred to the stage (Victorian Cursive writing style)  
Introduced Numbers: ability to drag and drop individual number (1-100) to the stage |
| Add mathematics signs (such as +, - and x) in some pages of the interactive story | Introduced maths symbols: ability to drag and drop the basic maths symbols (+, -, x, =) to the stage |

**Table 6.2. Requested requirements and actions to meet the needs**

Several other new media elements and objects were also included to cover different strands of the curriculum, including:

- **Map:** by clicking on this, a map of the village appears and users can show positions and pathways.

- **Clock:** by rolling over to the hour and minute hands and turning it clockwise, the clock time will change.
Farm elements: users can drag and drop all farm elements (vegetables, fruits, farm animals) to the stage.

Work area: or work stage, users can drag and drop all elements to this area as well as write, draw and erase.

Money sign: users can drag and drop Australian money signs ($ and c) to the stage.

Australian money coins: users can drag and drop 5c, 10c, 20c, 50c, $1, $2 coins to the work area.

Australian money notes: users can drag and drop $5, $10, $20, $50, $100 notes to the work area.

Shopping list: users can click and then create a shopping list.

Shopping elements: users can drag and drop all the shopping elements (grocery items) to the stage.

Shapes: users can drag and drop different shapes to the stage.

Grid: by clicking on this icon, a grid map appears.

Colours: users can drag and rollover an object (shape) on different coloured icons to change the shapes’ colour.

Bakery elements: users can drag and drop bakery elements (sweet and savouries) to the stage.

Slice tools: each icon will cut a pizza to proper slices.

Figure 6.3 illustrates a draft of the Interactive Storybook software’s design strategies in the story’s farm scene. Teachers can use the Interactive Storybook software to introduce, model, show or discuss many mathematics concepts related to the “Number and Place value”, “Fractions and decimals”, “Money and financial mathematics”, “Patterns and algebra”, “Location” and “Time” strands of the Australian Curriculum. First, the story reader icon reads the story aloud to children (using a familiar human voice - the same voice that was used in Tools 1) (Figure 6.3a), so that children can connect and become familiar with the
story’s theme, characters and setting. Teachers then can choose a scene (for example, the farm scene) (Figure 6.3b) and demonstrate a particular concept (for example, number and place value, skip counting or addition) through the use of interactive media (text box, pen tool, eraser, numbers) and the story’s elements (characters and farm elements). Teachers can also manipulate the story through interactive elements on the software and ask children how, why and what questions. Children can answer these questions through manipulating, adding, and removing objects around the screen.

Figure 6.3. Sample illustrations of the Interactive Storybook software design strategies - the farm scene
In the page with the title of “In the Shop”, the hero character (Hannah) delivers the elements that she picked up from the farm (such as eggs, basil and capsicums) to the shop and needs to receive money for these products. During the conversation (mathematics language) between Hannah and Sarah (the shopkeeper), Hannah calculates the price for each product. In this page, teacher can use the software to read the story and the hero character’s way of solving problems through listening to her voice and viewing the animations. They can also pause the story and pose questions to the children. In the next page of the software, multimedia elements and money and finance objects (Australian notes, coins and signs) can be used to create a new mathematics story to explain and demonstrate the concepts or to pose questions and ask children to solve the problem using the interactive elements in the software. The screen can be cleared (by clicking on the Sweep icon) for the creation of a new story. Teachers can introduce Australian coins to young children (in K - Year 1) by dragging and dropping different coins to the stage and talking to children about their shape, colour, value and by basic money counting. For older children, the teacher can create a shopping list with a specific price for each item and ask children to calculate the total price through using the story elements (shop objects and Australian notes and coins).

Teachers also can manipulate the time on the clock (changing the hour and minute handle on the clock) and pose question about the time at different places during the story. They also can use the map icon for explaining or posing questions relating to location and distance.

**6.2.2.2. Student Activity software**

During phase 1 participant teachers requested the inclusion of a movable text box and more story elements in the Student Activity software. To respond to this request, all objects from the storybook were included in the Student Activity software component, such as elements from the farm, bakery, shop and carpentry. This gave participant teachers many opportunities to create diverse activities through using a range of story elements (Figure 6.4).

For example, if the learning focus was on shape and pattern, the teacher could explain and model the concept through the carpentry setting in the Interactive Storybook by creating different stories about pattern, shapes, size and colours. Through describing the scene and
showing the concept, teachers could prepare children to gain knowledge and understand the concept first, before moving them gradually to the second software component (Student Activity software), where student individual practice and skill building took place. Children could practise their fluency skills by calculating answers, finding various answers and recalling factual knowledge and concepts readily through interacting, manipulating, and creating stories.

Figure 6.4. Tools 2- Student Activity software
In the Student Activity software component, teachers can manipulate activities to an appropriate level of difficulty and move students from one level of difficulty to the next. Teachers also can design activities in different formats according to their classroom needs (such as print, on a personal computer or through an interactive whiteboard).

### 6.2.2.3. Group Project software

To include all elements of the story (characters and objects) in the Group Project software, two sub-components named Group Project 1 and Group Project 2 were designed. Group Project 1 included all of the story objects, mathematics signs and multimedia elements used in the Interactive Storybook and Student Activity software (Figure 6.5). Teachers can pause a maths problem (for example, a mathematical word problem) and ask children, in pairs or small groups, to find a solution through the use of the story elements.

*Figure 6.5. Tools 2 - Student Group Project 1*
The Group Project 2 used the story's human characters and mainly focused on the concept of measurement, distance, basic grid, map location and time (Figure 6.6). This component can help teachers create a maths problem using the story characters, map and time.

For example, a teacher might create the following problem:

“Hannah left home at nine o’clock (change the clock hands in the screen to show 9:00) to go to the shop and bakery. It took her 10 minutes to go to Sarah’s shop (place Hannah and Sarah characters in the screen and draw a line between them) and 20 minutes to go to the bakery and return home (place the baker on the screen and draw lines between him and Sarah and Hannah). What time will Hannah return to her home?”

In this scenario, the teacher can verbalise the maths problem and drag and drop the characters to the screen or write the story as a word problem. To support them in calculating
the return time, children can use of the clock object and other elements on the screen.

The Group Project 2 also includes a function called “Map Grid”. Through this element, teachers can explain and create activities related to concepts of location, map-reading and distance. The Map Grid can help students learn about location, identifying places and reading maps. The grid uses lines to make rows and columns. The rows go from side to side and have a number to their left. The columns go from top to bottom and have a letter at the bottom (Figure 6.6). Every square on the grid can be referenced by a single row and column name (for example, B3).

The microphone feature, for recording children voices as they solve a maths problem, was also included in both components of the Group Project software.

6.2.3. Development

As previously explained, the IMDLC model was found to be useful in the development process of the educational interactive multimedia software. Through the structured process of the model, the Interactive Storybook software, Students Activity software and Group Projects software, which were designed in the ADDIE’s design phase, were created.

The originality of the story, the substantial number of elements (plots, characters, objects) and a lack of existing resources (images and illustrations) demanded that the researcher spend many hours on researching, drawing and designing individual elements of the story. For example, for illustration of Australian native plants such as eucalypts and the banksia plant\(^1\), the researcher studied Australian nature through the observation of real plants in the Australian bushes and botanic gardens. The design of the story’s characters also took into account Australia’s multicultural environment.

Alpha testing and Beta testing were conducted, as explained in Chapter 4, at different stages of this phase. Two primary school children, four K - Year 4 primary school teachers, two mathematics educators and one computer scientist were involved in testing and evaluating the software components. Some voice over mistakes and functionality problems

were detected through these testing process. For example, in the bakery page, teachers indicated that moving the knife tool over the pizza object for slicing (for teaching faction concepts, such as half and quarter) was difficult for young children to manipulate. The researcher’s observation (user study) of two children who tested the software identified this problem as well. This problem was addressed by introducing a set of icons that segment the pizza to the specific number of slices. For example, a user can rollover a pizza object to a “4 slices icon” and the pizza will be divided to 4 equal parts. Figure 6.7 shows the interactive multimedia software development process of Tools 2.
Figure 6.7. Tools 2 development phase, based on the IMDLC model
As previously noted, creating and including hand on materials (concrete materials) based on the story elements was one of the teachers’ requests from Phase 1. Therefore, in the development phase, a number of hands on material sets based on the story’s setting, elements and characters were designed and produced (Figure 6.8a). The hard copies of the storybook were published in big and small size books and distributed to participant schools (Figure 6.8b).

Figure 6.8. a. “Count on Me!” hands on materials, b. “Count on Me!” book in two different sizes

6.2.3.1. Formative evaluation

Pre-service teachers’ formative evaluation feedback and suggestions were found to be beneficial in the process of development of Tools 1. Therefore, another pre-service teachers’ formative evaluation was conducted after executing the Tools 2 development and before implementation of the software in schools. As in Phase 1, the developed tools were presented to pre-service teachers and early primary mathematics educators at a university in Western Australian (Figure 6.9). Through this process, 24 pre-service teachers and early primary mathematics teacher educators’ comments and suggestions were collected via questionnaire.
The analysis of pre-service teachers’ questionnaire and informal interviews findings indicated that there were no major technical issues in Tools 2. Some minor functional issues were identified, such as the voice narration was cut off in one page and the Eraser button did not work in one of the screen. These functional matters were resolved before implementation of the tools in schools. Table 6.3 presents a summary of pre-service teachers’ and mathematics educators’ responses to the technical and pedagogical features of the application, and below are some of their comments:

“The application has a lot to offer in maths classes. This could be used through the whole year for teaching and learning many maths concepts. Absolutely brilliant!!”

“Very related to the Australian Curriculum, flexible and open-ended.”

“Informative, fun, interactive… this [the software] will engage students and motivate their interest in maths”

“Excellent multimedia tools… the application allows teachers to create many activities for individual students … it also allows teachers to adjust what they want to teach in a particular lesson.”

“Transition from one concept to another concept is very smooth and it combines the mathematics concepts in the real word in very interesting and engaging way.”

“Allowing teachers to record children’s voices without making it obvious is a great feature.”
### Technical features of the My Maths Story software, Tools 2

<table>
<thead>
<tr>
<th>Feature</th>
<th>Rating (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The software has a professional look/presentation.</td>
<td>25% 75%</td>
</tr>
<tr>
<td>The screens are well-structured and the design is clear.</td>
<td>8% 92%</td>
</tr>
<tr>
<td>Menu, graphic, animation, audio and general layout interface are consistent.</td>
<td>25% 75%</td>
</tr>
<tr>
<td>It is easy to navigate through the application.</td>
<td>34% 66%</td>
</tr>
<tr>
<td>Multimedia elements are easy to find and use.</td>
<td>34% 66%</td>
</tr>
<tr>
<td>The application is enjoyable to use.</td>
<td>8% 92%</td>
</tr>
</tbody>
</table>

### Pedagogical features of the My Maths Story software, Tools 2

<table>
<thead>
<tr>
<th>Feature</th>
<th>Rating (%)</th>
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</thead>
<tbody>
<tr>
<td>Through the use of this application, learning mathematics concepts could be more enjoyable, engaging and motivating for children than when using other resources.</td>
<td>25% 75%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain and demonstrate mathematical concepts.</td>
<td>25% 75%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could explain ‘why and how’ questions relating to the mathematics concepts being taught.</td>
<td>26% 84%</td>
</tr>
<tr>
<td>Through the use of this application, the teacher could facilitate collaborative learning.</td>
<td>34% 66%</td>
</tr>
<tr>
<td>Young students (Years 1 to 4) could navigate the software.</td>
<td>58% 42%</td>
</tr>
<tr>
<td>It would be easy for student to create a simple mathematics concept story through the use of this application.</td>
<td>34% 66%</td>
</tr>
<tr>
<td>Through the use of this application, students could practise number facts.</td>
<td>26% 84%</td>
</tr>
<tr>
<td>Student could use this application individually or in pairs to analyse, explain and solve a mathematics problem.</td>
<td>25% 75%</td>
</tr>
</tbody>
</table>

Table 6.3. Pre-service teachers’ responses to some questions about technical and pedagogical features of Tools 2
6.2.4. Implementation

Tools 2 were trialled in 12 different schools (public, private and ESL) around Western Australia. The implementation started in February 2013 (the first term of school in Australia) and covered three school terms. Nineteen teachers and 494 students in the primary (K to Year 4) used the different components of the software in their classrooms. The tools were used with interactive whiteboards by the teachers to present explanations and demonstrations of maths concepts to the whole class. They were also used in school computer labs for individual and small groups work.

In each classroom, the use of the application began with the story being read aloud once by the computer narration with the children listening. For younger children, only the first few pages were read, and for older children the whole storybook was read. Some teachers invited children to think and predict what the story might be about before the story was read. Teachers also encouraged children to look at the illustrations in the Interactive Storybook and discuss the elements that they saw, such as the environment in which the story took place, what had been read, what the story was about, the characters, the role of the characters and the plot of the story. Through this discussion and focus on the elements of the story (characters, setting, plot), teachers attempted to capture students’ attention and to develop their comprehension (Figure 6.10).

Figure 6.10. Reading the interactive storybook
Teachers also used the story’s mathematics vocabulary (language) to pose questions and assess the students’ prior knowledge and understanding. For example, through reading the sentence in the book that says, “I need six cupcakes - half vanilla, half chocolate,” teachers posed the question, “What is the meaning of half?” Or in the page that says, “I need seven jars of jam - two jars of strawberry jam, one jar of cherry jam and the rest raspberry jam,” teachers invited children to think about the word “rest” and calculate the answer.

Teachers also discussed other, non-mathematical, vocabulary used in the book with their students. For instance, with reference to the word “carpenter”, teachers posed questions such as, “What is a carpenter? What does a carpenter do?” The word “basil” in the farm setting led teachers to ask children, “What is basil? Where we can find basil?” Where do we use basil?” Through this process, the teachers gained an understanding of their students’ prior knowledge and encouraged them to discuss and share this knowledge to others.

Throughout reading the story in the Interactive Storybook software, participant teachers paused the story and invited children to think about the questions that were asked in the story or the problem that the hero character (Hannah) was facing. Then teachers revealed the hero character’s solution to the problem by playing the story (story reader button). Students were able to see and hear the solution through animation and the narrated voice of the character in the Interactive Storybook software.

Participant teachers, depending on their class levels and learning objectives, used different sections of the story and the tools’ components for teaching various maths concepts. Teachers used the farm setting and elements to teach counting, place value, number sense, number relationships, skip counting, counting by sets of 2’s, 4’s, 5’s, 10’s, even and odd numbers, addition, subtraction and multiplication in different ways throughout the term (Number and place value). Teachers created various interactive stories by choosing the farm elements such as farm animals, fruits, vegetables, and appropriate interactive multimedia elements such as sound, animation, number, number words, mathematics symbols and text (Figure 6.11) and emphasised the intended learning outcomes or objectives by explaining the scene, retelling, and asking ‘why’ and ‘how’ questions.
The shop setting was used mainly for introducing and working on Australian money and finance. Participant teachers used the application’s shop setting for introducing Australian coins and notes, recognising and describing their value, and counting and ordering small collections of money for younger children. For older children, they used it to teach representing money values in multiple ways, counting money using notes and coins, calculating the change required for simple transactions to the nearest five cents, using $ and c symbols correctly, creating a simple shopping list and calculating the money needed to purchase items (Figure 6.12) (Money and financial mathematics).

Figure 6.11. Teachers using the “Count on Me!” Interactive Storybook software - the farm setting

Figure 6.12. Teachers using the “Count on Me!” Interactive Storybook software - the shop setting
In the carpentry setting of the Interactive Storybook software, participant teachers focused on patterning and algebra. They used the interactive elements to sort and classify carpentry objects and numbers and to copy, continue and create patterns with these objects and drawings. They also used the application to explain two-dimensional shapes, the basis for patterning and classification patterns with numbers formed by skip counting, and identifying missing elements. Describing number patterns and solving problems by using number sentences for addition or subtraction were also taught in this section of the interactive storybook (Figure 6.13). Some participant teachers used the simple grid function to draw and explain two dimensional shapes for comparing their areas, and for creating symmetrical patterns, pictures and shapes (Figure 6.14).
Teachers used the bakery part of the application to teach fraction and decimal concepts. They used the bakery elements to describe halves, quarters and eighths of objects and collections. Equal parts of a whole and counting by halves, thirds and quarters were also explained and demonstrated. Teachers represented unit fractions, including 1/2, 1/4, 1/3, and 1/5 and explained the connections between fractions and decimal notation. Figure 6.15 shows some samples of uses by teachers of the bakery setting of the story.

Figure 6.15. Teachers using the “Count on Me!” Interactive Storybook software - the bakery setting

Including the concept of time (clock) in the interactive software helped teachers to explain telling time using an analogue clock. They compared the size of the hands on the analogue clock and encouraged young students to use the clock object and turn the clock’s hands to indicate a time, telling time to the half-hour. For older students, they used the clock for telling time to the quarter-hour and encourage children to use the language of ‘past’ and ‘to’. Telling time using the analogue clock and writing the digital version of the time, and vice versa, were also discussed (Figure 6.16a) (Measurement and Geometry / Using units of measurement).

Teachers used the map feature of the software for explaining and interpreting a simple map (the village map), map symbols and cardinal direction. They used the village map for representation of the location of places and using directions to find features on the map.
Some teachers asked children to use the village map as a sample and to create a new place map, such as a school map or a school playground.

![Image of village map and clock](image)

**Figure 6.16.** a. Demonstration of time concepts (analogue and digital clock), b. the use of the software’s village map feature

The Interactive Storybook software assisted teachers in presenting and demonstrating various maths concepts through the familiar elements of the story and multimedia technology. They also used the Interactive Storybook for helping their students to recall facts, terms and concepts by remembering, describing and explaining (the “Remember” and “Understand” categories of the Bloom/Anderson model—lower level of the conceptual framework).

Participant teachers used the Student Activity software to create various mathematics activities for their students in different formats (interactive and print) and at different levels of difficulty (Figure 6.17). Furthermore, through interacting, manipulating, and creating various stories, children practised their fluency skills by calculating answers, finding various answers and recalling factual knowledge and concepts readily (the “Apply” category of the Bloom/Anderson model – middle section of the conceptual framework).
The Group Project software components were used for solving mathematics problems and concepts. Participant teachers used the Group Project 1 to create a story or a mathematics word problem and asked students to analyse, explain and solve the problem individually, in pairs or in small groups (Figure 6.18). Teachers also used the Group Project 2 software to generate mathematics problems relating to time (analogue and digital clock) and location (map and grid) (Figure 6.19). Units of measurement such as hours, minutes, kilometres and metres as well as their symbols (for example, KM for kilometre) were also used for creating and solving various problems (the “Analyse”, “Evaluate” and “Create” categories of the Bloom/Anderson model – upper level of the conceptual framework).
The hands-on materials that were created, based on the story's setting, elements and characters, were used in several classrooms, particularly in K-Year 2 classrooms, along with the interactive software. Some teachers divided the children into small groups and asked them to solve a maths problem that was related to one of the story setting, such as the farm, carpentry or shop, through use of the hands on materials (Figure 6.20).
The next section discusses the results and findings of the Tools 2 implementation in classrooms.

### 6.2.5. Evaluation and findings of Tools 2

All data, which was collected through semi-structured interviews, questionnaires and observations, were analysed through the data analysis process explained in Chapter 3. As mentioned in the Chapter 3, five themes were identified through the qualitative data analysis process, including: 1) Technological satisfaction in using the multimedia tools; 2) Applying cognitive learning objectives based on the Bloom/Anderson taxonomy; 3) Interactive multimedia technology for supporting mathematics pedagogies; 4) Curriculum alignment, and; 5) Perception of pedagogical practices on adapting new technology.

#### 6.2.5.1. Technological satisfaction in using the multimedia tools

The findings relating to the *Technological satisfaction in using the multimedia tools* theme are mainly consistent with the usability criteria defined by Nielsen (2003), including: learnability, efficiency, memorability, error and satisfaction. The findings indicate that both groups of target users, namely teachers and students, were able to accomplish diverse tasks through using the tools, without difficulty, from the first time they encountered the software interface (learnability, Mean ≥4.10) (Table 6.4a). They reported that the system was easy to learn so they could quickly and easily reach the level of proficiency in using the software (Table 6.4a).

“It was very easy to use and perform a task. [I had] no problem at all with the
software and getting it to work for myself and also for children, even the first time that they saw and worked with the software… very easy and straight forward” (T5, Year 2/3 teacher).

“The most important feature is that the software is so easy to use” (T1, Year 1 teacher).

“They [children] have been very good at using the software. I have not had any challenges in using it. It was simple and mainly dragging and dropping that both adults and children could do…there was a couple of times that they [children] told me how to do it and work with the software. They were kind of one step ahead of me and I did listen to them and we have done it together” (T3, Year 2 teacher).

“It [the software] was very easy to use and we didn’t have any specific challenges in learning to use it” (T8, Year 1 teacher).

Teachers reported that having a clean, simple, and structured layout design helped them to focus on a specific activity as well as performing the task quickly and competently (efficiency, Mean ≥4.21) (Table 6.4b). The findings from observations also indicated that, once users had learned the system, the tools were efficient to use and a high level of productivity was possible.

“I think, it [the software] was very clean and professional looking… having all the different icons at the bottom of each page was very helpful for me to quickly manipulate a task. All elements like buttons and icons worked fine for me and it was the same for my [class] children” (T11, Year 2 teacher).

“I didn’t find the whole setting too overwhelming. I found it is engaging but clear for kids to learn the software and follow… there’s not too much happening in the background; it was clean… in some software, sometimes, there’s too much happening and kids lose their focus and the whole point of the activity” (T17, Year 1 teacher).

“When I got familiar with the software, I understood that it is a fantastic tool for doing activities in a quick way… well presented and enjoyable to use” (T4, K teacher).
Findings show that the simple and easy characteristic of the system (mainly drag and drop functions) allowed users to return to the tools after some period of not having used it, without having to learn everything all over again (memorability, Mean ≥4.21) (Table 6.4c). Teachers highlighted that the system’s components, functions and interactive elements were easy to remember for most of their students as well.

“It [the software] was very easy to use. In fact, this time around, I have used it after a couple of months and it was still easy to move fast and to use the different parts of the software and create activities ... children also remember it very well. In some places, children been telling me what to do, for instance they said Mrs (teacher name), use the eraser icon to remove the line” (T6, Year 4 teacher).

During classroom observations, the researcher noted that some teachers were often using the “Help” menu of the software to remember a specific function of the tools or for extra information on using an icon or element. Most teachers used the user guide (help manual) online; however, some teachers preferred to read a hard copy of the instruction and keep it in their file for future use.

“...Having the user guide attached to the software was a great feature” (T2, K teacher).

“I found that including the help menu in the software was very useful…” (T10, Year 1 teacher).

The numbers of errors that were reported or observed in the process of trialling the software was low (Table 6.4d). In most situations, the error was minor or users were able to recover from the error quickly and independently. However, the main challenge and error shown were related to the technical issue of available ICT tools in classrooms, such as functionality problems relating to the interactive whiteboard, personal computers in the school lab or school internet connection issues.

“In terms of technology difficulties and software errors, it was the technology itself [hardware and network] that had a hiccup. For instance, my class interactive whiteboard did not work correctly…but the actual software was all right and the
entire thing that I had planned to do worked well. All the frustration was when
the technology tools [in this case, the classroom interactive whiteboard] were not
working properly” (T4, K teacher).

“It [the software] was easy to use and I didn’t have much difficulty. The only
challenge was that I was trying to print out the activity sheet but I couldn’t… then I
figured out that my computer had a problem and it worked fine on other computer…
and sometimes the voice was cut off, which I think was from our time to time low
speed internet connection in this school. It was easy to use for children as well…
the navigation was easy and children seemed to have no problem navigating and
following the software” (T15, Year 2 teacher).

Findings indicated that both teachers and children enjoyed using the Tools 2’s components
(satisfaction, Mean ≥4.52) (Table 6.4e). Using the software for a longer period of time (the
whole school year) and more often in the mathematics classroom and also being able
to use it in other subject areas (for example, science, English and history) were the main
usability satisfaction aspects of the tools.

The findings also show that use of appropriate colour, clear graphics, simple navigation and
familiar voice (a child’s voice with Australian English) and recognisable elements (characters,
objects and settings) in the software encouraged the users to continue using the system.
Teachers and students highlighted a number of reasons (as stated in below quotes) for
integration of the tools in their teaching and learning process that indicate technological
satisfaction attributes (see Table 6.4e).

“I love it absolutely and have used it many times in my class. It was colourful
and all the items are simple and the children understand them …like the use of
familiar elements that our kids know in Australia like in the shop; timtams, vegemite
(Australian products name) etcetera… When we were working in the money section
they [the children] could see they were actually buying things in the program that
they would buy in a real shop” (T18, Year 2/3 teacher).

“I think the software was very easy to use and professional looking… I like the fact
that a child is reading the story, I think it was very good way to engage children…
and the grammar was very good in it. In a lot of existing software, grammar is poor
and is not easy to understand and children try to decide what been said, which in this software, I felt they could understand the story, they could understand what had been read and asked…they like the presentation and graphics. Very happy” (T3, Year 2 teacher).

“I like when the screen reads the story for you… I think it is a good program because it’s easy to do. It is fun but still you learn about maths” (Year 3 student).

“It’s got a lot of maths and the more you read and do in the software the more you learn…she [the hero character] counts and calculates a lot. I like it. People like me want to learn new maths” (Year 4 student).

Teachers also reported their technological satisfaction of the tools through the availability of the software in different media (multimodal presentation). They indicated that access to the application in various presentation formats (such as interactive whiteboard, personal computer and print) helped them better address diverse student needs, including those of children with learning and physical difficulties. For example, a Year 1 teacher stated:

“There is a child in my class who suffers from hypermobility, which is condition that causes some joint and movement problems. Because of not having steady hands, this child is always having problems holding a pencil and writing on paper, but in the session that we used the Count on Me! Student Activity software, he was doing great. Because of the drag and drop function of the application, it was easy for him to do the activities on his computer while some of his friends were doing the same activity on paper…. Drag and drop and typing with the keyboard were much easier for him than writing with a pencil. He used the Group Project software with another student for a maths word problem as well” (T1).

A Year 2 teacher also said:

“I have a boy with autism in my class who was having difficulty engaging in group activities… today we used the hands on materials of the application and I set up the same activity on the class computer for this boy… my teacher assistant helped him to do the activity on the computer while other children used the hands on materials for solving a [maths] problem in small groups… I am very happy that he
was able to do the same activity but in different way…” (T11)

In summary (also shown in Table 6.4), the technological satisfaction of Tools 2 was reached.

<table>
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<tr>
<th>Criteria</th>
<th>Items on questionnaire</th>
<th>Rating (%)</th>
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<th>Min</th>
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<td>C</td>
<td>D</td>
<td>E</td>
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<td></td>
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<td>a. Learnability</td>
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<td>3</td>
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<td></td>
<td>Q 7</td>
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<td></td>
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<td>4.31</td>
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<td></td>
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<td>4.10</td>
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<td>37%</td>
<td>4.36</td>
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<tr>
<td></td>
<td>Q 7</td>
<td>79%</td>
<td>21%</td>
<td>4.21</td>
<td>5</td>
<td>4</td>
<td>4</td>
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<tr>
<td></td>
<td>Q 8</td>
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<td>5</td>
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<td></td>
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<td>5</td>
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<tr>
<td></td>
<td>Q 6</td>
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<td>26%</td>
<td>4.21</td>
<td>5</td>
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<td>d. Errors</td>
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<td>63%</td>
<td>4.36</td>
<td>5</td>
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<tr>
<td></td>
<td>Q 26</td>
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<td>21%</td>
<td>4.21</td>
<td>5</td>
<td>4</td>
<td>4</td>
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<td>e. Satisfaction</td>
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<td>63%</td>
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<td></td>
<td>Q 2</td>
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<td>53%</td>
<td>4.52</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
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<td></td>
<td>Q 4</td>
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<td>63%</td>
<td>4.63</td>
<td>5</td>
<td>4</td>
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<tr>
<td></td>
<td>Q 13</td>
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<td>68%</td>
<td>4.68</td>
<td>5</td>
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<td>5</td>
</tr>
<tr>
<td></td>
<td>Q 14</td>
<td>26%</td>
<td>74%</td>
<td>4.73</td>
<td>5</td>
<td>4</td>
<td>5</td>
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</table>

Table 6.4. Technological satisfaction evaluation of using Tools 2

6.2.5.2. Applying cognitive learning objectives based on the Bloom/Anderson taxonomy

The findings indicated that teachers were able to use the software to demonstrate and
explain their targeted mathematical concepts to their students. Through the use of the Interactive Storybook software component, teachers reached their intended learning objectives by explaining the scene, then introducing and demonstrating a particular maths concept to the students. Teachers indicated that the presentation of mathematics concepts within a story in a multimodal way helped them to express various mathematics concepts, helped them to retell, and supported them ask ‘why’ and ‘how’ questions.

“Because children get excited about the story, they are listening to it and want to know what happens next, so I can explain and demonstrate a maths concept while they are engaged and pose different questions” (T15, Year 2 teacher).

“The most important feature of the application is that I can go through the story and revisit and recall the concept that I want to explain” (T1, Year 1 teacher).

“It [the software] has been set up in a way that you can take it and adapt it to the level that you want and you need in your classroom. It’s open-ended and you can use different elements to explain and demonstrate different concepts. Today, as you saw, I demonstrated the division concept to the class” (T18, Year 2/3 teacher).

“I have done explicit teaching first and then moved them [the children] to the next level by posing different questions and asking them to find a solution and letting them to do it by themselves. I also used it by doing it in different ways to see if they actually understood the concept. I used the program for introducing a concept and the next day, basically explaining the same thing but doing it through different elements and twisting it around to see whether the children understood the concept or not…I like the way that this application allows you to do this” (T4, K teacher).

The tools also helped students to recall facts, terms and concepts by remembering, describing and explaining the story and mathematics concept. Teachers indicated that students were able to recall previously learned material and make a list of the learned facts. Several teachers reported that their students showed increased comfort levels in talking about their understanding of mathematics concepts and retelling the story in their own words. Through use of the interactive elements in the application, students made their own
stories and shared and discussed them in the classroom (Remembering and Understanding) (Table 6.5a). In response to the researcher’s questions about students remembering and understanding a variety of maths concepts through using components of the application, a Year 2 teacher stated:

“Yes, they [students] can remember and recall maths concepts through the motivation of the story and the story characters. My children have been engaged in the story very well and they remembered the story well and can recall it… when they remembered the facts, I manipulated the activity and made it a bit more difficult and asked them to solve the problem” (T11).

The results reveal that teachers used the program in different ways to support children in remembering and understanding mathematics concepts.

“I can use the program to introduce a new concept to my classroom and also extend what children already know to the next level. The story also introduces the concept of sequencing within real life problems … what happened and what might happen next? What happened after the mum left? Can you remember the list Mum wrote? What was the list for? These all are sorts of remembering tasks” (T2, K teacher).

“I had a teacher assistant reading the story and doing some activities with my children the other day… I followed up the story a week after and the children remembered the whole story and the maths activity that they had done with my teacher assistant. One of the students remembered and explained what the carpenter had made - she said the carpenter made four chairs and a table for Hannah” (T17, Year 1 teacher).

“In our computer lab session, I asked my class to open the software and then I asked them, ‘What do you think? Have a look around and see what you can do. The children explored the story and the mathematics concepts in the story and eventually they understood what the program was about. I didn’t want to say really anything myself to the children about the program; I let them explore and find what the program was about and explain to me their understanding…” (T14, Year 3 teacher).
Teachers also reported that they used the application for identifying their students’ level of knowledge and assessing their understanding about specific mathematics concept.

“As a teacher, you can be so creative in using this program… the other day, I was going to talk about [the concept of] half and quarter, so I thought, Count on Me! is perfect for me to understand where my children’s knowledge is in this area. I opened the software and showed the children the whole pizza and half pizza then I cut it into four slices and asked about the meaning of quarters… only one of my children knew about the concept of quarters, so I thought, OK, I need to teach them this concept. It [the program] gave me the baseline of children’s knowledge and then I knew where to go…. Basically, you are assessing children about what they already know” (T1, Year 1 teacher).

Another teacher supported this by saying:

“The first time that I read the story in the interactive whiteboard, it came to a dozen eggs at the farm… I was not quite sure that all my children knew what a dozen meant, so I asked, “What is a dozen?” and the children said, “It is 12 eggs,” and then I asked, “I wonder, if I have two dozen, how many eggs do I have?” and one child said it would make 24… It actually gives you some information about the children’s knowledge, what they already know and how many of them know that” (T2, K teacher).

Through interacting, manipulating, and creating various stories, students practised their fluency skills. Findings indicated that children were able to use the learned concepts in different situations through calculating answers, finding various answers and recalling factual knowledge and concepts readily (Applying) (Table 6.5b).

“I used it to demonstrate a maths concept and engaged children in the concept, then I let them play and explore and come up with their own story and create different stories and sums…through this exploration, they have practised their number facts and skill building” (T3, Year 2 teacher).

“Some facts, such as number facts and skip counting, are easily doable through this software. I used it for the concept of grouping on the interactive whiteboard
the other day and asked kids to work on the concept on their computer… You know what is good about this tool? You can present a subject on the interactive whiteboard and all the children can see it as a direct teaching method and explicit teaching, and then you can move them on to practise and apply the learned concept to different problems” (T4, K teacher).

“I found it useful for algebra concepts, through practising and skill building …which we are doing a lot in Year 2 and 3, and my children are weak on this area…. The Student Activity software was a great tool to develop these types of skills through the program and applying them to different situations. It is good seeing children learning and building knowledge like that”(T5, Year 2/3 teacher).

“…It [the software] helps them with their fluency as well; I think having the objects visual in the software and, plus hearing me talking about it and explaining it as well and getting something else from another child in the class, all help them to understand and building knowledge” (T2, K teacher).

Creating activities at different levels to suit students’ diverse skills and gradually moving them from one level to another was reported as a useful way to develop or maintain specific mathematics skills. Teachers indicated that, through this, children had been able to recall definitions and find and calculate various answers efficiently.

“It is so exciting that I can make them [activities] to the degree of difficulty that suit my students’ skill and create the activities according to my children’s needs. Because it is interactive, naturally my class can use it in different ways and at different levels of difficulty…They practised specific skills in the Money and Finance page to get fluent” (T6, Year 4 teacher).

“I started by reading the whole story, having a particular concept in mind, which I needed to reinforce. I have gone to the related page and worked on it… It is good for individual learning, letting children make their number story, and they can practise the number facts and then move to problem solving, especially maths word problems”(T5, Year 2/3 teacher).

“I liked the way it could be used as a tool to meet the different levels of the children in the class. There was flexibility within the program to move up and down levels
as the whole class lesson progressed” (T2, K teacher).

“I love the interactive side of the resource. The chance to create individual activity sheets is great as you can support your mathematical focus and the ability of children within the class” (T17, Year 1 teacher).

Findings indicate that the different components of the Tools 2 were used predominantly for mathematics problem solving and complex mathematics concepts that involve higher order thinking. Through the use of available components, teachers generated stories or mathematics word problems and asked students to analyse, explain and solve problems individually, in pairs or in small groups (the “Analyse”, “Evaluate” and “Create” levels of the Bloom/Anderson taxonomy) (Table 6.5c).

“…The higher order thinking and problem solving, understanding the problem and getting your answer for the problem are the part that I really like [in this program], and my children have done it in our computer lab sessions independently and in pairs. In the paired situation, one created a maths problem and the other came up with a solution for the problem. They talked to each other and explained what they were doing and I gave them feedback too” (T14, Year 3 teacher).

Findings showed that seeing the mathematics problem visually on the screen (in the format of text or as images) helped children to consider the details of the problem and work through these details to reach a solution. Teachers reported that, in solving mathematics problems, through using the story elements, students were able to breaks concepts into small components, select and combine appropriate objects (characters, numbers, mathematics signs), recall learned fact and process the relevant information to solve the problem.

“I have paused the story and asked children different questions and let them analyse and find answers… I let them discuss the problem and play with the story elements, numbers and [maths] symbols, then I played the story again and listened to the solution that the little girl in the story was telling” (T6, Year 4 teacher).

“In the group project software for problem solving, I found there is room to move them [children] to different levels while they are enjoying it because it [the software] is enjoyable and hands on. It is colourful and the illustrations are interesting to use
for them and they are attracted to it... so there is an excellent opportunity for me to pose different problems and to ask children to analyse and come up with their solutions in many areas.” (T6, Year 4 teacher).

Observational findings indicated that teachers used the microphone feature of the Group Project software often during the trial of Tools 2 for accessing and assessing children’s thinking while solving math problems, as well as identifying misconceptions. Teachers also supported this by saying:

“The microphone feature was a very good tool to detect the children’s mental thinking while they were solving problems... I also used it as an assessment tool” (T6, Year 4 teacher).

“The microphone feature was an interesting one for listening to children’s conversation and detecting kids’ mental thinking and the problem area that may cause a wrong answer, which is very common in mathematics problem solving, to make a mistake in a small part and cause the whole answer be wrong... and then I go back to them and explain to them the area of misunderstanding” (T15, Year 2 teacher).

“I like the recordings of children’s voices through the program, which is very powerful tool and is missing from other applications that I’m using currently. I can detect where the problem is through the recorded children’s conversations and go back to the children with a solution” (T14, Year 3 teacher).

“The microphone feature is good for presentation and recording children’s voices to detect problem areas as well. Also, I found it a good tool for accountability... you can record children’s thinking and when you are going to document their ability, or when you present it to their parents, you can actually show them what the child was doing through this recorded document...” (T4, K teacher).

“I have used the microphone feature. This feature is good for me because, I think I don’t [otherwise] record children’s voices as much as I should do...” (T11, Year 2 teacher).

A teacher who had not used the microphone feature, stated:
“I haven’t use the microphone feature; however, I can see it is a useful tool for assessment and detecting children’s mathematical thinking” (T18, Year 2/3 teacher).

A significant (100%) agreement was noted in response to the researcher’s direct question weather teachers noticed the Bloom/Anderson taxonomy and cognitive learning objective (the underpinning conceptual framework of the study) in the software. Some teachers’ responses were:

“This software, in terms of cognitive learning and the Bloom/Anderson taxonomy, really nailed it. Because I really think there are so many assets in the software… you can use it as a springboard and baseline and, talking about maths concepts, you can visually explain the concepts and relate them to the real world and tell children how maths is always around us every day. I have used it many times and certainly would use it again… I personally think I can use it for explicit teaching and setting up individual tasks, as well as group projects” (T8, Year 1 teacher).

“I can move from low levels to higher level of the Bloom’s [taxonomy] through the application and children can apply their pre-existing knowledge in a maths problem… I can design a task to target different ability levels for my class… for example, in the Money and Finance session, in the computer lab, I asked children to create and make different amounts. It was really fascinating to observe different ways that children applied our discussion in the classroom to use the finance elements and produce the different amount with Australian coins and notes. It is actually an open task, and I found that it is normally hard to create open task problems for this age group in my class, but this software made it easy to do…” (T1, Year 1 teacher).

“Yes, I can see the different levels of the taxonomy and have been moving my students from one level to another through different components of the software. The main thing is that the children loved it and enjoyed it and it’s been something different to other resources - it catches their imagination and they could create and make their own maths story and talk about it…” (T18, Year 2/3 teacher).

Table 6.5 summarises the teachers’ responses to applying cognitive learning objectives
Based on the Bloom/Anderson taxonomy.

### Applying cognitive learning objectives based on the Bloom/Anderson taxonomy

(n=19)

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<th>Items on questionnaire</th>
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<th>Mean</th>
<th>Max</th>
<th>Min</th>
<th>Median</th>
<th>Mod</th>
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<td>C</td>
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Table 6.5. Summary of the teachers’ responses to applying cognitive learning objectives based on the Bloom/Anderson taxonomy

### 6.2.5.3. Interactive multimedia technology for supporting mathematics pedagogies

As discussed in Chapter 2, many studies have indicated that interactive multimedia has the potential to contribute to and transform teaching and learning through a number of capabilities, including: motivation, engagement, supporting multiple representations, flexibility, feedback and collaborative learning.

Findings during the trialling of My Maths Story-Tools 2 indicate that the Australian based story, interactive multimedia components and connecting the mathematics activity to
real world problem were the main motivational elements of the multimedia program. It encouraged teachers to integrate the tools into their teaching and, according to teachers, it motivated children to use and work on different activities (Table 6.6a and 6.6b).

“Fantastic to develop these things [Australian based software] here, very well presented and enjoyable to use and it’s very appropriate. It is Australian based and has Australian accent and voice as well, which is familiar to our children. As a teacher, I need to find something which is practical, useable and suits my teaching method and also has diversity, which I found in this program” (T4, K teacher).

“It was a really good and happy story because the story set in a village, which takes you to a little bit of a slower mode of lifestyle and it relaxes you, in a way... I like the fact that it happens in Western Australia and it uses all the local elements and graphics, which children immediately relate to. So, for us, the relevance becomes doubled. It does show the Australian culture and balance in character theme [Australian multicultural environment and people]. Children find the icons and buttons easy to understand and to use because the graphics speak for themselves. The voice was very clear, as well as the grammar, and it worked in the same way and quality on different computers and on the interactive whiteboard” (T6, Year 4 teacher).

“I like the way that it is based on the Australian culture and environment, especially the Money and Finance section ... I had a problem with the other software that I'm using as we could not understand the accent of that software because it’s been developed in India. The whole aspect of the program is fantastic, the voice... kids love to hear... she [the narrator of the story] has got a lovely clear voice” (T14, Year 3 teacher).

According to participant teachers’ statements on the Likert scales (Table 6.6), learners’ willingness and interest and maintained interested in the activity (motivation, Mean ≥4.36) (Table 6.6a) and involvement in initiating and carrying out learning activities (engagement, Mean ≥4.36) (Table 6.6b) through using story and multimodal presentation. It was reported by several teachers that the children showed a desire to do the activities:

“The whole story is like a little land and they [children] can move to different sections
of the land in different parts of the story, which is very engaging and fun for them, and it is a real life story and they can relate to it, like going to shop and bakery and doing a task” (T17, Year 1 teacher).

Teachers indicated that demonstrating teaching concepts through story (Table 6.6e) and using different multimedia elements (text, graphics, animation, and audio) helped them to gain their students’ attention first and then they were able to direct students towards various learning goals.

“They [children] have been engaged in the story and like the fact a child is reading it, and seeing the graphics in the interactive whiteboard and also the drag and drop function, which they can easily do, and create their own story, make them more engaged (T3, Year 2 teacher).

“The colour and graphics were the big elements for the engagement and motivation to do more maths problem solving” (T7, Year 3 teacher).

“I thought it was a great program, the children really enjoyed the book and the technology aspects. It is a great tool to engage and inspire children to [mathematics] lesson” (T4, K teacher).

“I found it [the software] is very easy, and children really enjoyed the variety in it and they really enjoyed the concepts that come up in the story like the carpentry shop and the farm and bakery … it was visually appealing to them. We did talk about counting eggs at the farm, counting by 2s, 4s and 5s, and we looked at the patterns and did skip counting… doing these through characters and elements of the story were very engaging for children” (T16, Year 1 teacher).

Many teachers stated that the ease of use and interactivity of the software, as well as strong connections in the story to children's real life, motivated and encouraged children to be involved and to be proactive learners in the learning activities.

“It is engaging and appealing to children - you should have seen their face and expression in the first time that I just played the story on the interactive whiteboard…. they are so into it and love it and want to know more…. They love the story and relate to the story, it is age-appropriate and interesting for them” (T1,
Year 1 teacher).

“Children have been very engaged in the story, characters and graphics and the story was very relevant… the children could relate to it, because it was a little child in an Australian setting and culture and the settings like shops, the bakery and, because it was set on a farm as well. The farm was a different setting for them, so they have been interested in to it … They could relate to different elements, for example, going to the shops, bakery and the farm and helping the little girl and doing the jobs for the mum…so that was really good…good to explain about her sense of helpfulness as well” (T3, Year 2 teacher).

“I have never seen maths like this before… I like it because it is a story but has sums, money and a lot of stuff on it” (Year 2 student).

“It teaches how maths is fun…I learn half and quarter” (Year 2 student).

“It is very nice and also creative and it let you learn and also have fun…it is fun way to learn maths” (Year 4 student).

“It can be easy and also complicated but still fun…” (Year 3 student).

One of the features of Tools 2 that all participant teachers highlighted and spoke positively about during interviews was its ability to present and demonstrate information in more than one form (medium) to target diverse learning needs in the classroom (supporting multiple representations). Designing and producing the educational application in a multimodal way (interactive software, story book, printed and hands on materials) offered many opportunities to teachers to present various maths concepts using multimedia and to create diverse activities for children. Teachers reported that, through the combination of text and audio, and still and motion visuals in the multimedia software, as well as the provision of hands on concrete materials, helped them to present, explain and communicate information to children better (Mean ≥4.36) (Table 6.6c). Teachers also reported that demonstrating the same concepts through multiple representations helped the children to: a) benefit from the properties of each representation, and; b) learn in their preferred way such as verbally, visually or through doing.
“I liked having the whole package because some children are visual learners and some are oral learners and some like to do things with their hands. So, it’s better to have all the material available for them... some kids like to use hands-on materials so they can touch it and play with them physically, while on the other hand, some kids are happy and learn better if they do it through technology. They need to have all the experiences and choose which one is better for them. I think we can use the storybook for reading to the whole group and then the kids can practise on it, and get the skills with the interactive and concrete materials. It’s good to let them practise with the hands on material at this age so they can see it’s not just technology, and can use it in 2D and 3D. It’s just different experiences and learning styles...” (T4, K teacher).

"We have even used it today on the bakery page with cupcakes. I created a maths story and kept posing different questions with elements in the bakery page of the program such as, if I bought four cupcakes from the baker man and gave half of them to Miss William (one of the teacher assistants), how many would that be? How about if I have six cupcakes and gave half of them to Miss William? How many would be left for me? It is a visual presentation to children. As a teacher, I always look for opportunities to show the maths concepts in another way, multiple representations... I can use this tool to manipulate the story immediately and ask why and what happen questions in a fast and easy way. Last week, I used the farm elements, I dragged and dropped bunches of carrots and put a circle around them with the pen tool in the software and talked about the groups; it is reinforcing group concepts even though it is not written directly in the book” (T2, K teacher).

“ I can use the software as a teaching tool to explain concepts. The visual side of the application is really appealing to the children and I do have a lot of visual learners in my class... I show them visually one concept would definitely help them to concentrate and learn... having the clear little mathematical signs in there [software] to introduce them to the children were really helpful elements... children become aware of different mathematical signs and having the signs always down in the bottom of the software was a good way of raising awareness for children, although I’m not using it at all the time for my teaching. The software definitely interested them and, definitely, they can practise different tasks through this software”(T17, Year 1 teacher).
“I like the way that it used the child’s voice. It was a really good way to engage children and the pace is good and it is not too fast. I’ve got some good readers in my class and some are still in the Foundation [level] and are in their early stages of reading… so having that slower pace of reading and the text underneath, it was good and easy for them to take it in and understand the story and questions…” (T17, Year 1 teacher).

“…As a teacher, through this tool, I can support children’s different learning styles and abilities …definitely it [the software] is not just targeting one concept or one group, it is a really flexible and open-ended resource and I definitely can extend the kids’ learning to the next level” (T12, Year 1 teacher).

The flexibility (open-endedness) of Tools 2 was identified as a significant advantage with regards to being able to integrate the application into teaching and learning processes. Participant teachers indicated that the dimensions of flexibility (listed below) increased opportunities for them and their students to control their teaching and learning through a variety of modes and interactions. They mentioned that a range of options were available to choose with respect to their teaching and learning goals and objectives (Table 6.6d). The reported flexibility of the Tools 2 includes:

- Flexibility in using different components of the software to explain and demonstrate various mathematics concepts;
- Flexibility in the ability to create, adapt and provide differentiated instruction;
- Flexibility in the types of interactions possible; for example, explicit teaching and scaffolding, individual practice, group work and collaboration;
- Flexibility in forms of communication, such as through interactivity, print or hands on materials;
- Flexibility in creating materials and the ability to create diverse activities at different levels through the interactive tools or the printed materials;
- Flexibility in location, for example the ability to use the software in the classroom, computer lab or at home;
“[It] is covering a lot of content but it is very open-ended and flexible. I have used [it] in my class many times to explain fractions, money, multiplication and division. Even yesterday, when I was planning [my maths lesson], I was thinking, ‘What am I going to do today?’ I remembered the Count on Me! program and thought, ‘What can I do with it?’... I am going to use the farm elements today, for addition, subtraction, and multiplication’” (T1, Year 1 teacher).

“It is a good tool to not necessarily just follow the kind of storyline, but to use as springboard to open up a mathematics concept... it is very open-ended and flexible. [it] saved my time to create all the materials... I can also demonstrate my immediate feedback to the children when I am asking some questions [such as] ‘Is there another way that you can do it?’ And eventually pushing them to the next level...”(T2, K teacher).

Teachers indicated that the flexibility and open-endedness of the program allowed them to modify the application according to their classroom needs and to provide feedback to children (Table 6.6f), as well as offering them the flexibility to present concepts in an innovative manner.

“What I was doing was to get the farm and money and finance page up - I had introduced them the concept of 10th before but had not introduced the concept of money yet - so I have used the farm elements to remind children of the concepts of 10th then I moved them to the money and finance page and presented the Australian coins for the concepts of 10c, 20c, 30c. For example, I said, ‘This carrot cost me 10c. I wonder how many 1 cents are in 10 cents?’ So I can see that I can use the program to introduce a new concept to my class and also extend what the children already know to the next level - very flexible. For me as a teacher, I will have look at the page of the book and software and I think, ‘What else I can do in this page?’” (T2, K teacher).

“There is a lot of scope in the software. The thing that I like about this software is, it [allows for] extension of individual concepts like addition and subtraction. Although my children are very young and they are kind of doing basic things in this area, I do have children in my class that are more able and I can extend them to next level, so this software was good for these children to be extended and also to be
able to let them go and find the solution themselves…. I divided them into different groups and let them go and work as a small group and work out maths problems” (T2, K teacher).

“I used it a lot and am going to continue using it for rest of this year … I like to use the book, software and concrete material all together. The good thing about this program is you can concentrate on one page and explain the concept and then move to a related activity. The software has a lot of potential, is flexible and open-ended” (T10, Year 1 teacher).

“I love the big book, hands-on activities and interactive storybook. I could break it down [the story] to small portions and subjects and just to do a small section. I could ask children to solve a problem on the interactive whiteboard … then I could see how they had done and give them feedback and extend them to next level” (T11, Year 2 teacher).

Teachers were also able to facilitate active approaches to learning through involving children in activities individually, in pairs or in small groups (collaborative learning) (Table.6.6g). Teachers indicated that the different types of interaction that were facilitated by the software motivated children in their learning and provided them with many ways to express their ideas and present their knowledge and understanding. In response to the interview question regarding whether teachers could facilitate individual and group learning methods through using the tools (See Appendix A), teachers stated:

“Yes, students have used it individually and in small groups... I rotated children, so two or three were working on the same maths problem...sometimes, they worked independently, other times in a small groups...because the teacher can’t be with them all the time … but we need to know what they have learned and what they have discovered and how they help each other, so the microphone feature was a very useful tools in this situation… so I could detect the problem area and go back to the child and teach them that missing concept… they [might] have just missed a step that caused them to get the answer wrong” (T2, K teacher).

“Definitely, it’s a good tool for collaborative learning, like today what they have done as a small group [in a patterns and shapes activity]. They can use it and they
can stay on task” (T15, Year 2 teacher).

“Yes, children were able to use it individually as well as working in small groups. The way that I’ve done it is, I asked one group to make a problem and give it to another, so in this way two groups have been engaged in one maths problem” (T14, Year 3 teacher).

“Yes, because it is easy to access and load up on different computers, children can use it individually and as small groups” (T5, Year 2/3 teacher).

“Yes, I did pose questions and ask them to work it out together and it was also good for them - interacting with others. It was good for children to listen to other children’s thoughts and how they think in solving a problem” (T4, K teacher).
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Table 6.6. Participant teachers’ evaluation results on interactive multimedia technology for supporting mathematics pedagogies

6.2.5.4. Curriculum alignment

Its alignment to several strands of the Australian Curriculum was noted by participating teachers as being one of the main benefits of using Tools 2 in classrooms. All participant teachers stated that they could integrate several strands of the Australian Curriculum into their teaching through the use of the application. Findings show that the flexibility and open-ended nature of the tools provided teachers with the ability to teach different substrands
of Number and Algebra (e.g. Number and place value, Fractions and decimals, Money and financial mathematics and Patterns and algebra) and Measurement and Geometry / Location and transformation (Table 6.7). In particular, the Australian money and finance section was highlighted by a number of teachers as an area that they had used many times in their classroom.

“The tools linked very well to the Australian Curriculum, especially Mathematics and ICT. I can explain different concepts and link them to different parts of the Australian mathematic curriculum, for instance in the carpentry, I used it for pattern and measurement. In the shop, I used it for introducing money and financial [concepts] and in the farm there is a capacity to create a maths problems at different levels in an engaging way... Today I have created activity sheets which focus on Australian money value” (T6, Year 4 teacher).

“It definitely overlaps with a lot of the Australian Curriculum, and it is connected to literacy as well, and all the mathematical language in there was very useful and huge... How the characters of the story ask questions, that was very useful for children to think about. There are so many learning areas in there” (T17, Year 1 teacher).

“I can connect to ICT, and different mathematics strands of the curriculum through this software, including: Number and algebra, Patterning and Finance. Finance is massive in the Australian Curriculum and money is the area that children are definitely weak in, and creating real life situations for using money and introducing the money value and engaging them and then asking them to solve a finance problem was great. Sharing different solutions for solving a particular maths finance problem was another good thing about this program” (T5, Year 2/3 teacher).

“Definitely, I can link it to different areas in the curriculum - Money and Finance was great. Use of money and the fact that children can see Australian money and currency and use it was a very important component of the software. I used it for number, quantity, counting, addition, patterning, number sense, subtraction and basic division. I still can do and explore around many other concepts such as time and basic measurement... It [the software] lends itself to a lot of areas and it’s very open-ended” (T7, Year 3 teacher).
Besides the alignment with the mathematics curriculum and ICT, a number of teachers reported that they had used the application in other curriculum areas including literacy (English), Science and History. Although, the Count on Me! book and software were developed for teaching and learning mathematics, because of the Australian based culture and nature of the application, several teachers used it in their English, Science and History/culture teaching. A Year 2 teacher expressed this by saying:

“…However, the program is predominantly for maths but you can connect it to different subjects like science, reading and history. You could get children to read the book in the reading lesson and ask children for comprehension, at the same time using it for their maths as well. You can tell them, ‘Now you know the story and you understand the story, let’s do the maths!’ [You can] move different objects and bring out different concepts and ask them mathematics why and how question” (T3).

Most teachers mentioned the connection of the program to literacy, as well as the usefulness of the tools for explaining mathematics vocabulary and other vocabulary embedded in the story.

“There is a big connection between literacy and mathematics in this program. The thing that I like about the book and software is that it gives you opportunities to use language skills as well; it is not just the mathematics or mathematical languages, but a lot of vocabulary that my children need to know… We want them to know what is a capsicum, what is a herb…you know, for my children, and many of them [have] English as second language, they need to know a lot of basic vocabulary that is in the book if you are going to pose a maths problem to them. I have to make sure that all the children know the vocabulary first… for example, when the book was talking about bunch of basil, I posed a question, ‘What is basil?’ and one of my children said, ‘Oh, I think we used it in cooking,’… so I said, ‘That is right, it is kind of herb. Does anyone know what a herb is? Then we got a bit sidetracked about what a herb is, but it does not matter... it helps them build their understanding of the new vocabulary. There are many new vocab [words] in the program and this is connected to their literacy” (T2, K teacher).
“It is related to lots of parts of the Australian Curriculum for me, because I have done counting, take away, addition, patterning, number sense and grouping for the maths criteria part and it also gives me the opportunity for literacy because it is an Australian literacy book with Australian characters and nature which makes that literacy criteria… We read the story on the interactive whiteboard three or four times, just listening and reading the story. When we started, they [the children] were beginning readers, but now they have started picking the actual words and can read it themselves… It is interesting to see them going from one level to another level in both maths and English” (T10, Year 1 teacher).

“We were working on mathematics vocabulary and language a lot through the program, such as the rest, equals, sum… that is what’s good about this book and software. I can say, “Oh, this is the sum symbol, what does that mean?”… Again, it is reinforcing the concepts that we are trying to use and explain to the children in an engaging way” (T2, K teacher).

“It does connect very well with literature [from the English curriculum] and I did use it for mathematical language and also storytelling. I probably could use it a bit more in this area as well and go to deeper in different units and different mathematical language. I do feel that I can do lot with this software; it’s covering a lot of concepts and it helps me to teach and explain different concepts, not just in mathematics activities but also integrating it in other things that I’m doing, like science” (T15, Year 2 teacher).

“[A]gain, it was quite interesting that we talked about different types of books this week as our Book Week activity, and I actually discussed this book with my class as a storybook that help them learn maths … very exciting to talk about literacy, maths and science all through one program, because in early primary we try to connect all subjects together. You can do all these things because all are available in the program” (T5, Year 2/3 teacher).

With regards to implementing Tools 2 in the science classrooms, a number of teachers explained that they used the Interactive Storybook software for explaining Australian native plants and Australian nature. A few teachers reported that they used the farm setting section of the software to encourage children to identify vegetables and herbs that children could
grow in their school garden (as part of a school science project). In the history class (Society and Environment), teachers asked children to think about the story characters, their names and appearances, and where they may have come from and discuss their thinking with other children.

“I also used it for our science class… one day, we just back from Kings Park [a botanic garden in Western Australia] excursion and we had been talking about Australian nature, the Banksia flower, Kangaroo paw and other things like the park’s maps … when we got back to the school, I opened the software and all sort of things that we saw in our excursion were in the storybook software, so it was very relevant and it made sense to children…. We reviewed what we learned on the excursion through the software as our science lesson and then moved to the maths concepts” (T5, Year 2/3 teacher).

“We used the software in science for Australian nature… we are planting our vegetable garden now, so I have used the farm page to show and explain all sort of vegetables that we can grow in Australia…” (T10, Year 1 teacher).

Table 6.7 summarised the participant teachers’ responses to questions relating to alignment to the Australian Curriculum of Tools 2.

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Table 6.7. Summary of teachers’ responses to questions relating to alignment to the Australian Curriculum of Tools 2
6.2.5.5. Perception of pedagogical practices on adapting new technology

Findings indicate that teachers’ technological knowledge and feeling competent in using technology has influence in their acceptance of using the new technologies in a particular learning area. Although participating teachers stated that the developed tools were easy to use and aligned with their pedagogies, their lack of self-confidence and “insecurity in using technology” were mentioned as major concerns regarding adapting the new technology in their teaching and learning activities.

“In terms of technological challenge, it’s more me and my technological knowledge, and also my insecurity in using the technology rather than the software being technologically challenging. Apart from that, the software was easy to navigate and relevant to my teaching beliefs” (T7, Year 3 teacher).

“Not as an issue with the software, my main issue is the technology of the whiteboard itself and it might be a bit of me and my technology knowledge, not the software” (T18, Year 2/3 teacher).

Teachers’ lack of confidence in adapting the new technology was observed more among experienced participant teachers as opposed to younger teachers. However, the confidence and self-competence of experienced teachers appeared to increase, along their willingness to accept the potential value of using the new technologies, after they received training and ongoing technical support from the researcher. The findings (mainly through observations) also indicated that explaining the pedagogical affordances and constraints of the tools and emphasising the alignment to the Australian Curriculum encouraged teachers to incorporate the tools into their teaching and learning. Teachers reported that they were able to use the new technology in their teaching practice often and more effectively after a training session that demonstrated possible uses through demonstrating a range of features available in the tools.

“I thought it was quite easy to follow, and having you in here for the first time to guide me through was very good, because I’m a person who, if somebody shows me how to use a tool, I learn better. I am a visual person. I prefer to be shown and then I can fiddle around and used it in my teaching... So it was good to have you
here to show me. If I was going to do it myself, I wouldn’t be proactive and use all functions” (T4, K teacher).

Accessibility of ICT equipment in the schools (such as the availability of sufficient personal computer in classrooms or in the school lab) and having a teaching assistant or other helper in the lower grade levels (K- Year 2) was another element that affected the integration of the new technology in teaching and learning process. Teachers who had a Teacher Assistant or parent helper were able to use the software more often for individual learning or group project collaborative learning, as opposed to whole class teaching. Teachers explained: “At this age [K- Year 2], children still need individual help to use personal computer” (T1), for example to login to a computer or solve technical issue such as making sure the sound system is working. On the other hand, teachers who did not have enough help used the tools in their classroom to conduct whole class lessons, using the interactive whiteboard to explain subjects, which involved inviting children to solve a maths problem on the interactive whiteboard. A Year 2/3 teacher stated:

“I haven’t had a chance to use it [the software] in our computer lab often because it is quite hard to work in the lab as I need an assistant to help me for setting up the children … But I appreciate and I can see how well it can be used by individual at the computer or working as pairs” (T18, Year 2/3 teacher).

“They [the children] have been working independently and in small groups in the lab… it was good to have my Teacher Assistant and a parent helper here to help us” (T1, Year 1 teacher).

In answer to the researcher’s question that focused on comparing Tools 2 with the previous software (Tools 1), and the question about the participants’ likelihood of using the Tools 2 in the future, teachers responded:

“Definitely, I would use it as resource, especially having it as whole package resource including hands-on materials, because if we have the whole things as a package, children can use and manipulate it and use it individually and also collaborate as a group. I think it is much more interactive than the first software… the first software was more specifically maths, especially for the lower end [K-Year
2 classrooms], whereas [in] this one [Tools 2], you can start from K and go to Year 4. That’s a good thing about this software - the flexibility of use, and also the concept of time and the map which are included in the second software are very appropriate and realistic to the children’s everyday life” (T7, Year 3 teacher).

"Absolutely, it is covering many concepts and has many materials; for instance, the new concept introduced in this software, like the map and time. We can talk about time, direction and calculation of time as well. This is a concept that children in my class still need to work on it. Because it is visually appealing to children, I can pose a lot of maths problems in the area of measurement, distance and time. Because children can imagine it and see it, they are able to understand and fix a problem” (T6, Year 4 teacher).

"Now I know this software, I’m going to use your first software as well because the ‘One is a Snail [Ten is a crab] software is more concentrating on basic numbers and its great for the beginning of the year for introducing numbers and how to write a number and number sense, grouping, patterning and all this sort of stuff. I will probably use that one first and eventually move children to the second software” (T4, K teacher).

"I haven’t had a chance to use your first software but I’m going to use it at the beginning of next year and can’t wait to show it to my classroom” (T10, Year 1 teacher).

In response to the interview question (Appendix A) about changing or adding new features to the program for future use, several requests were noted:

1. Creating the program for mobile and touch devices, such as the iPad;

   “I will use both of the programs as they are great resource packages which include hands-on materials, books and the interactive software all together. I would like to have iPad versions as well” (T8, Year 1 teacher).

   “I would like to have it [the software] in the iPad as well, because you can have one iPad for two children and they could discuss what they doing and move the object around…you could have ten groups, exploring different concepts… I think it has
great potential for use on the iPad” (T3, Year 2 teacher).

“Having it [the software] on the iPad would be great as well. It would be wonderful if we could set up children with this program on individual iPads” (T1, Year 1 teacher).

2. The availability of black and white outline versions of the Student Activity sheet;

“I used the activity sheet as well, but we don’t have a colour printer in here, so it would be nice to have the activity sheet available in black and white because I like it when the kids finish the activity and still have time, they can colour in - so a black and white outline would be great” (T10, Year 1 teacher).

 “[Regarding] the activity sheet, I would rather have not colour pictures, so children can colour in themselves” (T19, Year 1 teacher).

3. Breaking the story up into smaller sections or placing a pause button in the interactive storybook:

“I would like to pause the story and let children to finish it … just a couple of times I wished I had a pause button … to let children think or for me to pose a question. The other elements, like buttons and icons, work fine for me” (T11, Year 2 teacher).

In summary, evaluation findings regarding Tools 2 indicated that teachers and students were able to use the multimedia application in their classrooms for modelling, sharing and discussing a range of mathematics concepts within a story in a multimodal way.

6.3. Chapter conclusion

This chapter has presented the process of implementation and evaluation of Phase 2. Through a second iteration of the ADDIE framework cycle, My Maths Story - Tools 2 was designed, developed and implemented in several K- Year 4 classrooms. In the absence of appropriate subject matter content for addressing the teaching and learning requirements identified in Phase 1 of this study, the researcher wrote and illustrated “Count on Me! A Mathematics Adventure Book” which was used as basis for the multimedia application.
The IMDLC model was applied in the development process of the educational multimedia software system. Tools 2 were trialled in 12 primary schools for 3 terms during 2013. Both qualitative and quantitative data were collected and analysed on an ongoing basis (see Chapter 3). The findings of the evaluation have been presented through five themes, including: Technological satisfaction in using the multimedia tools; Applying cognitive learning objectives based on the Bloom/Anderson taxonomy; Interactive multimedia technology for supporting mathematics pedagogies; Curriculum alignment, and; Perception of pedagogical practices on adapting new technology.

The next chapter concludes this thesis with a discussion on the study’s findings and the implications. It also answers the research questions and provides number of recommendations for further research and practice.
This chapter discusses the findings of the two phases of the study and answers the research questions. The chapter is organised into two main sections. The first section provides an overview of the research and discusses the study’s findings in relation to the three research questions. In answering the questions, a number of the models and frameworks that the study proposed and applied in the development and implementation of the mathematics educational multimedia applications, My Maths Story, are discussed. The second part of this chapter discusses the limitations of the study and makes suggestions and recommendations for further research and practice. The chapter concludes with the study’s original contributions to knowledge in the contexts of education, computer software development and instructional system design.

7. 1. Overview of the research and the research questions

The impetus for the research was that, while educational multimedia software has the potential to provide successful teaching and learning experiences for both teachers and learners, few educational applications fit well in Australian primary school settings to facilitate mathematics learning in a manner that is considered to be pedagogically appropriate by teachers. Disconnections between theory for designing educational applications and
theory relating to the application of technology in classrooms, as well as a lack of alignment between technology and curriculum and pedagogy, have been highlighted in this thesis as major issues that have limited the quality and relevance of existing computer-based educational applications in Australia.

This thesis argues that, to provide successful teaching and learning experiences through the use of multimedia applications, a suitable approach should be taken. The approach needs to be based on pedagogical principles that are accepted by the teachers concerned, general human-computer interaction principles, as well as relevant educational theory and research. Consideration needs to be given to both the technical aspects of interactive software design and to pedagogical aspects, including integration into the curriculum and teachers’ pedagogical beliefs and practices.

It has been necessary in this study to structure the research approach in a way that not only allowed an evaluation of the usefulness of multimedia software through data collection and analysis, but also investigated and justified the process of design, development and integration of such complex systems in educational contexts. Figure 7.1 illustrates a summary of the research approach, data collection and evaluation used to identify the technological and pedagogical criteria and answer each of the research questions that guided this study.
Figure 7.1. Summary of links between the research questions, research activities, data collection and evaluation criteria in the research study
The following sections discuss and answer each research question.

7.1.1 Q1. Can a framework based on the support of cognitive learning objectives through story be used to inform the design and development of interactive multimedia software for primary (K-Year 4) mathematics education?

The findings of this study support the proposition that in the design and development of educational interactive multimedia applications, a suitable educational framework is needed. These findings are derived from the process of implementation and different developed themes, particularly findings from the Applying cognitive learning objectives based on the Bloom/Anderson taxonomy theme. The findings support the findings of previous studies (Laurillard, 2009; Mumtaz, 2000; Patten, Amedillo Sanchez, & Tangney, 2006) that much existing educational software is not considered by teachers to be usable in their teaching because they are often not designed with an acceptable underpinning educational theory and pedagogical frameworks.

The findings of this study indicate that the proposed conceptual (educational) framework provided a strong foundation for designing multimedia mathematics software for use by teachers in primary school (K- Year 4) classrooms. The My Maths Story mathematics educational applications utilised the framework, which was constructed after a review of the literature, discussions and interviews with K- Year 4 teachers and the researcher’s observation and investigation of existing computer-based applications in mathematics classrooms in Australia. Through this, it was possible to:

- Identify and select the Bloom /Anderson taxonomy as a suitable underpinning theory for the proposed framework;
- Identify and select storytelling, skill building (fluency building) and problem solving as three effective approaches to mathematics education for young children that are aligned closely with the main components of the Bloom/Anderson taxonomy;
- Identify approaches to facilitate individual and collaborative learning when using the software;
- Identify multimedia elements that can assist in facilitating cognitive learning objectives at different levels and support teachers’ preferred teaching strategies.
This study found that embedding mathematics concepts within a story and presenting it in multimodal ways can help teachers to explain and demonstrate various mathematics concepts. Teachers indicated that they used the application to retell, to ask ‘why’ and ‘how’ questions, and to create open-ended problems to encourage children to think and apply strategies for solving problems (cognitive learning) (Anderson et al., 2001). Teachers reported that teaching concepts through story in multimodal ways helped them to gain their students’ attention first and then direct students toward various learning objectives. The study's findings indicate that the use of story and interactive multimedia elements in mathematics lessons helped children to recall facts, terms and concepts by remembering, describing and explaining scenes and characters (which contained maths concepts) in their own words (Krause, et al., 2006; Tucker, et al., 2010) (the "Remember" and "Understand" categories of the Bloom/Anderson model-lower level of the conceptual framework).

The findings also indicate that students were motivated to learn because they were interested in the story and the multimedia technology. This study supports the idea (Chang et al., 2011; Clark & Mayer, 2011; Grabe & Grabe, 2007; Kozma, 2003; Mayer, 2003; Ward, 2005) that the use of pictures, audio, animation and informal, familiar language helped children to grasp the abstract subjects such as mathematical ideas and concepts more keenly.

The findings indicate that teachers used the multimedia application to assist children in consolidating their knowledge of mathematical facts and help children solve problems fluently and with confidence through the creation of mathematics activities in different formats. Through interacting with, manipulating, and creating various stories, children practised their mathematics fluency skills by calculating answers, finding answers and recalling factual knowledge and concepts readily. For example, participant teachers stated that readily counting numbers in sequences and continuing patterns was achieved by children through regular practice in their classroom (the "Apply" category of the Bloom/Anderson model – middle section of the conceptual framework). Participant teachers noted that repetitive practice helped children achieve fluency and enable them to “move to the next level” and attend to the more complex activities of problem solving and higher-order processing (Tait-McCutcheon, et al., 2011).
Participant teachers used the different components of the multimedia application, especially the Group Project components, to create stories or mathematics word problems and to ask students to analyse, explain and solve the problem individually, in pairs or small groups (the "Analyze", "Evaluate" and "Create" categories of Bloom/Anderson model-upper level of the conceptual framework). Teachers reported that when solving mathematics problems, seeing the mathematics problem visually on the screen helped children to consider the details of the problem and work through these details, break concepts into small components, select and combine appropriate objects (characters, numbers, mathematics signs), recall learned fact and process the relevant information and knowledge to reach a solution. This finding supports some previous studies findings such as Lazakidou & Retalis, 2010; Wilburne et al., 2011.

In this study, the strong underpinning educational framework, alignment with early years and primary mathematics pedagogies and teaching beliefs, as well as alignment with many strands of the Australian Curriculum, were highlighted by teachers as major reasons for integrating the new multimedia application into their mathematics teaching. One of the key findings of this research is that many teachers had the desire and motivation to use the application in their classrooms because of the strong underpinning educational framework.

Statements such as:

“I am a big fan of Bloom’s taxonomy and I am using it in my teaching…I have noticed the details of the taxonomy in the program. For instance, in the group project work, it is a higher order thinking and there is room to move them [students] to different levels while they are enjoying it because it [the software] is enjoyable and hands on… there is a room for me to use it [the software] in many areas” (Year 4 teacher).

In summary, to answer the research question, the findings indicate that an educational framework based on cognitive learning objectives through story can assist in the design and development of effective educational multimedia software for use in the primary mathematics classrooms.
7.1.2 Q2. How can educational interactive multimedia software, based on supporting cognitive learning objectives through story, be developed to address the needs of both teachers and students in the primary (K-Year 4) mathematics classroom?

It has been mentioned in the literature that disconnections between theory for designing educational applications and theory relating to the application of technology in classrooms, as well as the lack of alignment between technology, curriculum and pedagogy, are issues that can limit the quality and relevance of existing computer-based educational applications (Mumtaz, 2000; Robin, 2008; Offer & Bos, 2009; Yelland, et al., 2001). It is also stated that teachers do not tend to integrate existing software in their teaching and learning processes because these application are more concentrate on the technology of the software system itself and are rarely based on the requirements of education, in terms of both learners’ and teachers’ needs (Morehead & LaBeau, 2005; Patten et al., 2006). Miscommunication between software developers and end users during the process of analysing and understanding users’ requirements and needs (needs analysis), and unsuitable use of multimedia in terms of educational content, are other problems associated with educational software (Carbonara, 2005; Morehead & LaBeau, 2005; Patten, et al., 2006; Sim, MacFarlane, & Horton, 2005).

As demonstrated throughout of this thesis, the research study reported here aimed to address this disconnection and lack of alignment through:

1. Proposing and applying an educational framework based on the Bloom/Anderson cognitive learning objectives and accepted mathematics pedagogies for the early primary years;

2. Selecting and applying an appropriate Instructional System Design (ISD);


The details and outcomes of using the educational framework have been discussed in the previous chapters (Chapter 5 and Chapter 6) and in answering Research Question 1, earlier in this chapter (section 7.1.1). The following paragraphs discuss the importance of using Instructional System Design and the new Interactive Multimedia Development Life Cycle (IMDLC) model.
This study used the ADDIE instructional system design as: (a) an organising framework for reaching the educational objectives, and; (b) a tool to close the gap between the theory for designing educational applications and theory concerned with applying educational program for teaching in mathematics classrooms. This study applied a user-centred approach, which puts the target users’ needs and requirements, rather than the system, at the center of the process.

This research’s experiences indicate that instructional system design can be used as a bridge between what the researcher of this study refers to as the “Education domain” (teachers’ and students’ language) and the “Computer software domain” (software developers’ language) (Figure 7.2). The gap between education and computer software domains has been conceived of as miscommunication and misunderstanding between software developers and end users in previous research (Carbonara, 2005).

As shown in Figure 7.2, the first phase of the ADDIE instructional system design, Analysis, is close to the education domain, because this phase discusses and analyses the language and attributes that are related to and familiar to the teachers and students, such as analysis of teaching and learning needs, target users’ characteristics, subject matter, pedagogical objectives, teaching and learning objectives and the learning environment. The development
phase is normally conducted by software designers and uses developers’ language (computer software domain). This can be viewed as a transitional stage that transforms the planning of instructional materials (from the Design phase) to a production mode to produce software to be used in the teaching and learning environment (the Implementation phase). During this research, the formative evaluation that took place during the different phases of the instructional system design ensured that these two domains were well connected. It also enabled the researcher to determine whether teachers and students would be able to use the software product to meet their teaching and learning objectives, and how it could be improved before implementation in real world settings.

The findings of this research show that in order to design and develop suitable educational software, the application of an instructional system design is beneficial. As well as being used as an organising framework for reaching educational objectives, instructional system design can be used to assist in the transition from the educational domain (teaching and learning needs) to the development of useful educational software (the computer software domain), and returning to the education domain for implementation and evaluation.

As has been found in previous research (Cairncross & Mannion, 2001; Clark & Mayer, 2011; Doolittle et al., 2005; Engels, et al., 2003; S. Mishra & Sharma, 2005) and also demonstrated in this study, multimedia software has the potential to provide successful teaching and learning experiences for both teachers and learners; however, the development of such applications for effective use in an educational context is a complex task. As mentioned in Chapter 4, in software system development, the operational function is usually the main focus of the software designers (Clark & Mayer, 2011; Engels, et al., 2003; S. Mishra & Sharma, 2005) while this study argued that to create educational multimedia software, knowledge of software development (computer software domain) is necessary but not sufficient. Further, this study has argued that in the design and development of any useful educational interactive multimedia software application, with the guidance of educational framework, the following three activities should take place: 1) user interface development, 2) software development, and 3) media production. These three activities should be based on general human-computer interaction principles as well as accepted pedagogical principles, in terms of both learners’ and teachers’ needs.
In the absence of a universal methodology for the development of educational interactive multimedia software, this study has introduced a new model, which is underpinned by cognitive theory and multimedia learning principles. Clark and Mayer’s multimedia design principles helped the researcher to understand how the cognitive processes of interpreting visual and auditory information can affect learning. The IMDLC model assisted in the My Maths Story multimedia software system’s functional development and helped the software developer (in this case, the researcher) develop the content, identify the interactive elements, and design and use the best media to present content in an effective manner to each user. The IMDLC model not only described the technical process of the software development but also its value in the teaching and learning environment, understood through a comprehensive set of educational principles within different phases of the model, as well as guidelines from the ADDIE instructional system design and the educational framework of cognitive learning objectives, which were based on the Bloom/Anderson taxonomy.

Findings of this research indicate that using recognisable elements (such as using a friendly human voice for audio narration and using familiar characters), and adding only material that supports the instructional goal through a well-presented graphical user interface, can result in reduction of cognitive load (Clark and Mayer multimedia cognitive learning principles). This research found that applying a cognitive theory of multimedia learning in the design of an educational multimedia application helped users focus on the learning content rather than on understanding or operating the functionality of software tools. Some of participant teachers’ statements supported this, such as:

“I didn’t find the whole setting too overwhelming. I found it is engaging but clear for kids to learn the software and follow... it’s not too much happening in the background, it was clean ... in some software sometimes too much is happening and kids lose their focus and the whole point of activity” (T17, Year 1 teacher).

The findings support previous research studies (Clark & Mayer 2011; Galitz, 2007) that suggest that cognitive load demanded of computer users can be significantly reduced through the implementation of a well-presented graphical user interface and the exclusion of extraneous information in the form of background sound, added text, and added graphics.
This findings also support other studies (such as Doolittle et al., 2005; Mayer, 2003) that suggest that when an application is in the form of multimedia, the relationship between cognitive load and instructional design are very important elements to be considered throughout the design and development process.

The evaluation findings, particularly the findings drawn from the Technological satisfaction in using multimedia tools theme, indicate that the My Maths Story interactive multimedia educational software systems met the technological needs of both teachers and learners in the K-Year 4 classrooms. The findings also reinforce the view that, to get the best outcomes from technology, educational computer-based resources need to be designed with the requirements of teaching and learning as the starting point (Laurillard, 2009). Communication with end users and ongoing user involvement is encouraged throughout the lifecycle of the development process.

The findings of this research indicate that there should be a link between theory for designing educational applications and theory relating to the teaching contexts in which the software is intended to be used. This study has found that, in the development process of educational software, the technical (operational function) aspects of the interactive application and the context in which it will be used are both important. This finding is consistent with several previous studies that have found this disconnection to be one of the main reasons that software is often not integrated into classroom practices (Cairncross & Mannion, 2001; Carbonara, 2005; Hinostroza & Mellor, 2001).

In conclusion, in responding to the second research question (“How question”), a development framework is illustrated (Figure 7.3). Different parts of the framework were applied in the development process of the educational multimedia software (Tools 1 and Tools 2). The framework advocates an iterative approach to the design and integration of an educational multimedia software application. The researcher suggests that the framework could be used or adapted in similar projects; teachers and educators, technology instructional designers and software developers can use or adapt the framework in creating new multimedia programs.
Figure 7.3. A development process framework for the creation of educational interactive multimedia software
7.1.3 Q3. Can the developed educational interactive multimedia software be incorporated into K- Year 4 mathematics classrooms to support pedagogies and enhance mathematics teaching?

The discussion provided for this research question mainly draws upon findings from the *Interactive multimedia technology for supporting mathematics pedagogies, Curriculum alignment and Perception of pedagogical practices on adapting new technology* themes.

In this research, the limitations of many computer-based application, Australian mathematics teachers’ needs, teachers’ technological knowledge and their classroom technology limitations were investigated through extensive activities at the beginning of the study (through classroom observations and interviews with teachers and early primary mathematics teacher educators). One of the aims of this research was to reduce these limitations and barriers through the development of interactive multimedia software that was based on a well justified educational framework, Australian teachers’ beliefs and their pedagogies in mathematics teaching, as well as a close alignment with the curriculum in Australia.

As discussed in the literature review, teachers can apply a range of approaches to teaching mathematics through storytelling that are cognitively stimulating, authentic and exciting for their students (Goral & Gnadinger, 2006; Haven, 2000; Robin, 2008; Thiessen, 2004; Ward, 2005; Wilburne, Keat, & Napoli, 2011; Wilburne, et al., 2011; Zazkis & Liljedahl, 2009). The previous study also showed that interactive multimedia has the potential to contribute to and transform teaching and learning through a number of different capabilities such as motivation, engagement, supporting multiple representations, flexibility and collaborative learning (Cairncross & Mannion, 2001; Clark & Mayer, 2011; Genc Ilter, 2009; Maushak et al., 2001; Roblyer et al., 2006; Wiken, 2005). The findings of this study show that through the careful selection of story and multimedia components, teachers were able to provide a rich and engaging context for promoting children's mathematical explorations, reasoning and critical thinking from K- Year 4. This research found that the presentation of mathematics concepts within a story through multimodal representations enabled teachers to use story and multimedia components for reaching a variety of learning objectives. They
generally did this by explaining the scene, then introducing and demonstrating a maths concept to their students (cognitive learning processing) (Anderson et al., 2001). They thus used children’s literature as a bridge to connect the abstract and symbolic language of mathematics to children’s own world through meaningful conversations and explanations of mathematics language. Teachers were able to select various multimedia elements and use the characters, objects, plot, theme, setting, timeframe, and illustrations in the story to identify situations in which real life mathematics problems may exist, or explain mathematics concepts and pose questions. The findings show that the presentation of mathematics concepts within a multimodal story, and the options provided for teachers to select pictures, audio and animation to tell mathematics concept stories, helped teachers to explain various mathematics concepts much easier and faster than in traditional ways.

The My Maths Story applications offered teachers many opportunities to share and discuss a range of mathematical concepts for various ability levels, within the motivational context of a story that linked mathematical concepts to real world events and settings. Teachers were able to use the interactive applications to introduce many mathematical concepts relevant to their classroom and curriculum. Furthermore, teachers and students were able to generate their own stories by choosing appropriate characters, settings and multimedia content. Students also had opportunities to interact with the story and introduce variations (and even to pose their own problems) to permit engagement with relevant concepts more thoroughly and deeply.

The interactive multimedia applications were found to be helpful to learners with diverse learning needs. Participant teachers reported that the application helped them to present and demonstrate mathematics information through various media to support specific kinds of learning, including the ability to support student with physical (such as hypermobility) and social difficulties (for example, children with autism).

The research findings show that using children’s literature and multimedia technology with a focus on reading, writing, and communicating mathematically, is an effective way to motivate, engage and inspire children to explore mathematical concepts actively and enthusiastically. This finding supports previous studies that identified storytelling as an

Findings of this study also indicate that familiar and Australian based elements in the story and connection of the mathematics learning activities to real world problems through interactive presentation was one of the element of motivation in using the multimedia program in the teaching and learning. This finding supports the view that using real life and familiar elements in a meaningful story, coupled with using personalisation in multimedia elements, such as using a human voice with a standard accent rather than a foreign accent or a machine voice, can first motivate and engage children in learning about mathematics concepts and then help them to connect the abstract and symbolic language of mathematics to their own world (Clark & Mayer, 2011; Tucker et al., 2010; Ward, 2005; Wilburne et al., 2011).

The flexibility or open-endedness of the program was also identified by participants as an advantage of the program, since this encouraged teachers to integrate the multimedia tools in their teaching and to motivate children to use and work on different activities. Participant teachers also indicated that the simplicity and consistency of the user interface helped them and their students to reduce time needed to learn about the technological functionality of the software and thus to increase productivity (Clark & Mayer, 2011; S. Mishra & Sharma, 2005).

Alignment of the interactive multimedia application with the curriculum in Australia was found to be an important factor in whether teachers integrated it into their teaching and learning practices and programs. The findings show that, because of the strong alignment of the software with broad strands of Australian Curriculum (Mathematics, English, Science and History), teachers were able to integrate various strands of the curriculum into their teaching through the use of the application. They selected different strands of the curriculum for their classes and used the interactive software, looking for opportunities to relate the story to the strands or connect the strands to the various elements of the story (one of the approach identified by Wilburne et al., (2011) for using children’s literature in teaching and learning). This finding indicates that in the design and development of educational
software, curriculum integration must be considered. Failure to pay attention to how the software might be integrated into the curriculum may result in it not being used, regardless of how well it is designed in terms of software technology and functionality (Cairncross & Mannion, 2001). This result also supports studies that claim that the lack of curriculum alignment in many existing computer-based applications is one of the main reasons for them being rejected by teachers (Mumtaz, 2000; Robin, 2008; Yelland, 2001).

The lack of provision for collaborative learning through existing software, which is often underpinned by behaviourist principles and thus entails individual, repetitive and quiz-based activities, has been highlighted as a shortcoming of many existing educational applications (Laurillard, 2009; Pifarré & Staarman, 2011). In this respect, participant teachers of the study indicated that the My Maths Story applications were better aligned with their preferred pedagogies because they could use them in classrooms as teaching tools to model, share and discuss a range of mathematical concepts with children, as well as to facilitate learning activities by children, as individuals, in pairs and in small groups.

During the course of the research, the researcher provided a number of professional development sessions and ongoing technical support to help teachers integrate the new software into their teaching and learning process and to improve teachers’ confidence in using the developed tools. Participant teachers, including teachers who initially had a negative attitudes towards integrating technology into their teaching, described these supports as beneficial and reported that they felt competent to integrate the new tools into their pedagogical practices through receiving ongoing support and training. This finding is aligned with other research that states that a lack of effective training, lack of accessibility to appropriate resources and lack of technical support are factors that influence a teacher’s integration of technology in the classroom (Balanskat, Blamire, & Kefala, 2006; Bingimlas, 2009; DET, 2006; Jones, 2004; Pelgrum, 2001).

In summary, this study found that interactive multimedia software, My Maths Story, which was designed and developed using a well justified educational framework and took into account teachers’ pedagogical beliefs and mathematics teaching pedagogies, supported and enhanced participating teachers’ mathematics teaching.
7.2. Limitations of the study

One of the main aims of the study reported here was to create and integrate interactive multimedia software as mathematics educational tools. In this study, teachers and students successfully used My Maths Story as educational tools in their teaching and learning. However, the study mainly focused on the teachers as users of the application and teaching aspects of the software tools. The research investigated and studied the outcomes of using software on children’s learning as reported by teachers; however, additional study is required to investigate children’s learning in more detail.

7.3. Recommendations

Based on this study’s findings and the researcher’s experiences during the design and implementation of the educational software tool, several recommendations can be made. Researchers, teachers, educators, technology instructional designers and software developers may consider these recommendations and suggestions to inform the development and integration of educational multimedia applications in the teaching and learning of a range of concepts across the curriculum:

1. In designing educational multimedia applications, an extensive study needs to be conducted in the early stage of project to identify learning objectives and suitable underpinning educational theories.

2. Subject matter (for example, mathematics) pedagogies that are acceptable to the teachers concerned should be identified through discussion with teachers, and a review of relevant literature needs to be conducted before the design of multimedia materials commences.

3. A review of the curriculum and an analysis of how to integrate the multimedia application into the curriculum should be considered at an early stage of any project.

4. Development of an educational framework, which incorporates learning approaches (for example, behaviourism, cognitivist and constructivism or combination of any) as a basis for designing the multimedia application.
5. Selection and application of a suitable Instructional System Design (ISD) or Instructional Design (ID) model as a guideline for reaching the educational objectives is recommended. The selected framework can also be used as a bridge for communication between education and computer domains.

6. Human-computer interaction principles (technical aspects), pedagogical theory (pedagogical aspects) and the integration of interactive multimedia into the curriculum, should be considered.

7. Understanding multimedia technology features and design principles such as the Clark and Mayer (2011) multimedia principles, and how these features can be used to add value in a given teaching and learning context.

8. Identification of interactive multimedia technology benefits, for example, support multiple representation and it shortcomings such as cognitive overloading in teaching and learning.

9. Applications of a software development model (such as the IMDLC model), which covers the activities of user interface development, software development, and media production, with the guidance in educational theory.

10. Involvement of end users throughout the lifecycle of the design, implementation and evaluation of the educational application. This can help in identifying areas where multimedia can add value and can also help pinpoint problem areas.

11. Conducting ongoing formative evaluation during the process of design and development of educational application, and constant communication between end users, instructional designers and software developers.

12. Professional development for end users, to demonstrate the features of the educational application and to show how it might be used in the classroom, should be included in the implementation process.

13. Provision of the multimedia educational application to end users through different formats (interactive software, print and hands on materials) and system delivery (online, software installation, CD/DVD) depending on user requirements and available ICT tools in schools.
14. Evaluation should not end with the introduction of the interactive application in the teaching and learning environment. The usefulness of the application should be monitored as an ongoing process and technical support needs to be provided after launching the application.

15. To enhance evaluation and the understanding of the effectiveness of educational technology in teaching and learning, the collection and analysis of data from a range of sources is recommended as this type of evaluation and data can provide more rounded and richer picture of a given teaching and learning situation.

16. The design, development and integration of educational multimedia software is a complex task and can be extremely time consuming and expensive. Thus, in the implementation of such a project, conducting a pilot study or distributing the project across different phases to examine and investigate the practicality of the educational framework and educational multimedia software are recommended.

7.4. Concluding remarks and contributions

The presented research study contributes new knowledge in a number of areas, including; the education context (for researchers, teacher educators and teachers); the computer software context (for educational software designers and developers), and; the instructional system design context (for technology instructional designers). These contributions are explained throughout the thesis and are summarised below:

1. The identification of the limitations of existing computer-based software in the area of mathematics education (contribution to research literature);

2. The identification of Australian teachers’ needs and requirements to inform the development of Australian based educational mathematics software (contribution to the educational context);

3. The development of a new educational framework based on cognitive learning objectives, teachers’ pedagogies and beliefs for informing educational software design (contribution to the educational context, Figure 3.4 and Figure 3.5);
4. The development of a novel educational multimedia software development model (contribution to computer software context-IMDLC model, Figure 4.4 and Figure 4.18);

5. The proposal and use of the Instructional System Design as a bridge for communication between education and computer languages (closing the gap between the educational domain and the computer software domain) (contribution to instructional system design context, Figure 7.2);

6. The proposal of a development framework, which advocates an iterative approach in the design and integration of an educational multimedia software application (contribution to all three above contexts, Figure 7.3);

7. The writing and illustration of a new mathematic educational storybook for Australian teachers and children (Count on Me! A Mathematics Adventure Book, shown in Figure 6.8 and Appendix I), which is currently available in many Western Australian classrooms and school libraries;

8. The design and development of two educational interactive multimedia software tools (My Maths Story - Tools 1 and Tools 2) for the teaching and learning of mathematics, which are currently accessible in Western Australian schools.

7.5. Conclusion

Educational multimedia software should be based on teachers’ and students’ needs and requirements in order to become an useful and applicable educational resource but the design and development of such user-centred software is a complex and time intensive task. The integration of a new application into teaching and learning processes and encouraging teachers to use it can be difficult, time consuming, and resource intensive. This research shows that teachers need time working with new educational software before they will be at a level of confidence to integrate it into their teaching. Teachers’ training and ongoing technical support are needed. This research also indicates that in the design and development of educational interactive multimedia software, consideration to the technological aspects of the software and pedagogical aspects of integration into the curriculum, as well as teachers’ pedagogical beliefs and practices, are important.
In conclusion, the My Maths Story applications appear to hold considerable potential for teaching mathematics in the primary (K- Year 4) mathematics classrooms through storytelling and the use of multimedia technology to support the attainment of cognitive objectives at all levels. This research supports the claim that, when it is based on pedagogical principles that are acceptable to the teachers concerned, the use of multimedia for teaching abstract subjects such as mathematics can provide successful teaching and learning experiences for both teachers and learners.
REFERENCES


Theory into practice, 47(3), 220-228.


APPENDIXES
Appendix A: Semi-structured interview

MY MATHS STORY SOFTWARE AND TEACHING AIDS
(TEACHER’S INTERVIEW QUESTIONS)

This interview questionnaire is an instrument to evaluate the technical and pedagogical features of the “My Maths Story” application. “Count On Me!” is multimedia educational software within the My Maths Story application, and is based on “Count On Me! A Mathematics Adventure Story Book” by Nasrin Moradmand. This educational software is fundamentally an Interactive Storybook based on current pedagogical views of mathematics education and the Australian Curriculum, and aims to assist in the teaching of mathematics concepts in the lower primary school classroom.

Your feedback as a teacher who has used this application is important as it informs me as to how this application might help teachers to integrate educational experiences that incorporate interactive multimedia software based on a storybook into the teaching of mathematics.

Name ..........................  School ..........................  Grade ..........................

A. General questions

1. Could you describe your experiences in using the Count On Me! software and associated teaching aids for teaching mathematics concepts in your classroom?

2. What challenges, if any have you experienced in using the software?

   a. With regards to the challenges you experienced, do you think these could be overcome or minimised by the application designer? How?
B. Technical feature questions

In your experience of using this software:

3. Does the software have a professional and appealing look/presentation? (If No, please explain).

4. Was it easy for you to learn and navigate through the application? (If No, please explain) Was it easy for children to learn and navigate through the application? (If No, please explain).

5. Was it easy to find and use the buttons and multimedia elements? (If No, please explain). Was it easy for the children to find and use the buttons and multimedia elements? (If No, please explain).

6. Was the language in the software and in the user's guide clear to you? (If No, please explain).
C. Pedagogical feature questions

7. Did this application assist you in demonstrating and explaining a range of mathematical concepts to your students? How?

8. How did the software help you teach the Number and Algebra strand (Number and place value; Money and financial mathematics; Fractions and decimals; Patterns and algebra) of the Australian Curriculum?

9. How did the software help you teach the Measurement and Geometry strand (Using units of measurement) of the Australian Curriculum?

10. What do you think about the role of story and characters in explaining mathematics concepts to your students?

11. Could you link mathematics and literacy (cross curricular links with literacy) using the software? If so, would you please explain how you did this?

12. Could you explain ‘why and how’ questions relating to the maths concepts being taught through the use of this software and teaching aids? How?

13. How did the software help you target individual learning needs, if at all?

Based on your experience of using this software and teaching aids in your classroom:

14. Could you facilitate collaborative learning in your classroom? How did you do this?

15. Could students use the application independently?

16. How well were students able to imagine the story scenes, retell the story and describe scenes and characters in their own words?

17. Do you think the software assisted children in learning facts? Could you please explain how?

18. Do you think the software assisted children in their skill building/fluency? Could you please explain how?

19. How well were students able to create a simple maths concept story using the software? Could you please explain how?
20. How well were children able to use the software in pairs or small groups to analyse and find solutions to maths problems?

21. Could the whole class share and discuss a range of mathematical concepts at various levels, using the software? How?

22. Do you think students’ critical thinking was encouraged through the use of this software and teaching aids? If yes, how?

23. Have you used the microphone feature of the software (for recording children’s voices)?
   If yes: a. Do you think this feature helped you to observe and assess their mathematics thinking processes? How?
   b. Did this feature help you to target your teaching? How?

24. Have you used the hands-on materials, which were provided to be used in conjunction with the software?
   If yes: Have you found them useful as teaching and learning tools? How well did these materials help you to teach mathematics concepts to your students?

D. Concluding questions

25. Would you use this software and the teaching materials in your classroom again (for future use)? Why is that?

26. Would you use this interactive storybook and teaching materials instead of or alongside the traditional version of the book in your classroom? Why is that?

27. In your opinion, was this software better than the first software you trialled (One is a Snail, Ten is a Crab)? In what way?

28. This software was designed using Bloom’s Revised Taxonomy as a theoretical base. In your opinion, how useful is the software for helping children think about mathematics at different levels?
Appendix B1: Questionnaire

MY MATHS STORY SOFTWARE AND TEACHING AIDS QUESTIONNAIRE

This questionnaire is an instrument to evaluate the technical and pedagogical features of the "My Maths Story" application. “Count on me!” is multimedia educational software within the My Maths Story application, and is based on “Count on me! A mathematics adventure story book” by Nasrin Moradmand. This educational software is fundamentally an Interactive Storybook based on current pedagogical views of mathematics education and the Australian Curriculums, and aims to assist in the teaching of mathematics concepts in lower primary schools classroom.

Your feedback as a teacher is important as informs us as to how this application might help teachers to integrate educational experiences that incorporate many proven learning theories into the mathematics curriculum. This questionnaire has three sections. Please consider each item carefully and choose the most appropriate response.

Your Name (optional) ____________________________________________

A. Technical evaluation of the software

A. Strongly disagree   B. Disagree   C. Undecided   D. Agree   E. Strongly agree

<table>
<thead>
<tr>
<th>Technical feature of software</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The software has a professional look/presentation.</td>
<td></td>
</tr>
<tr>
<td>2. The screens are well-structured and the design is clear.</td>
<td></td>
</tr>
<tr>
<td>3. Menu items are clear and easy to remember.</td>
<td></td>
</tr>
<tr>
<td>4. Menu, graphic, animation and audio elements and the general layout interface are consistent.</td>
<td></td>
</tr>
<tr>
<td>5. It is easy to navigate through the application.</td>
<td></td>
</tr>
<tr>
<td>6. Buttons are easy to find and use.</td>
<td></td>
</tr>
<tr>
<td>7. Multimedia elements are easy to find and use.</td>
<td></td>
</tr>
<tr>
<td>8. It is easy to drag and drop a graphic.</td>
<td></td>
</tr>
<tr>
<td>9. It is possible to navigate from one page to another page without difficulty.</td>
<td></td>
</tr>
<tr>
<td>10. It is easy to switch from one element to another element.</td>
<td></td>
</tr>
<tr>
<td>11. There are consistent links between pages.</td>
<td></td>
</tr>
<tr>
<td>12. It is easy to switch from one topic to another topic.</td>
<td></td>
</tr>
<tr>
<td>13. A suitable combination of colours is used in the application.</td>
<td></td>
</tr>
<tr>
<td>14. The application is enjoyable to use.</td>
<td></td>
</tr>
<tr>
<td>15. In my opinion it would not require major previous computer experience (for children) to use the software.</td>
<td></td>
</tr>
</tbody>
</table>

Comments and suggestions for improvements of technical features of the software:
__________________________________________________________________________
B. Pedagogical evaluation of the software

<table>
<thead>
<tr>
<th>Pedagogical feature of software</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>16. Through the use of this application, learning mathematics concepts is more enjoyable, engaging and motivating for children than when using other resources.</td>
<td></td>
</tr>
<tr>
<td>17. Through the use of this application, the teacher can explain and demonstrate mathematical concepts.</td>
<td></td>
</tr>
<tr>
<td>18. Through the use of this application, mathematical concepts are linked to the real world.</td>
<td></td>
</tr>
<tr>
<td>19. Through the use of this application, cross-curricular links with literacy can be achieved.</td>
<td></td>
</tr>
<tr>
<td>20. Through the use of this application, the teacher can adapt their teaching to target a variety of learning objectives.</td>
<td></td>
</tr>
<tr>
<td>21. Through the use of this application, the teacher can explain ‘why and how’ questions relating to the maths concepts being taught.</td>
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</tr>
<tr>
<td>22. Through the use of this application, the teacher can direct learning and provide information about topic.</td>
<td></td>
</tr>
<tr>
<td>23. Through the use of this application, the teacher can facilitate collaborative learning</td>
<td></td>
</tr>
<tr>
<td>24. If discussion took place, the teacher could moderate it and respond to students’ questions, through the use of this application.</td>
<td></td>
</tr>
<tr>
<td>25. Young students (K to Y4) were able to learn and navigate the software.</td>
<td></td>
</tr>
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<td>26. The software allowed for student reflection.</td>
<td></td>
</tr>
<tr>
<td>27. It was easy for students to create a simple maths concept stories through the use of this application.</td>
<td></td>
</tr>
<tr>
<td>28. Through the use of this application, students’ critical thinking and analysis could be encouraged.</td>
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</tr>
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<td></td>
</tr>
<tr>
<td>31. Through the use of this application, teacher can address Number and Algebra and Measurement and Geometry strands of the Australian Curriculum.</td>
<td></td>
</tr>
<tr>
<td>32. Student can use the hands on materials (which have been offered alongside this computer application and are based on the characters in the story) beside the software for practising mathematics activity.</td>
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</tr>
<tr>
<td>33. Through the use of this application, the whole class could share and discuss a range of mathematical concepts at various levels.</td>
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<td>34. Students could use this application individually or in pairs to analysis, explain understand and solve problems.</td>
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<tr>
<td>35. A variety of interactions (teacher /student and student/student) could take place, through the use of this application.</td>
<td></td>
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</table>

Comments and suggestions for improvements:
C. General comments

36. If you could choose, would you use this software and the teaching aids in your classroom?
   
   Yes  No
   Comments: Why/Why not?

37. Would you use this interactive book and teaching aids instead of the traditional book in your classroom?
   
   Yes  No
   Comments: Why/Why not?

38. In your opinion, this software was a step forward from the first software (One is a Snail, Ten is a Crab)?
   
   Yes  No
   Comments: Why/Why not?

Please describe what you did like /not like about using this software?

Approval to conduct this research has been provided by the University of Western Australia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time. In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Research Ethics Office at the University of Western Australia on (08) 6488 3703 or by emailing to hreo-research@uwa.edu.au. All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.
MY MATHS STORY SOFTWARE AND TEACHING AIDS QUESTIONNAIRE

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Your feedback as a future teacher is important as informs us as to how this application might help teachers to integrate educational experiences that incorporate many proven learning theories into the mathematics curriculum. This questionnaire has three sections. Please consider each item carefully and choose the most appropriate response.

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A. Technical evaluation of the software

A. Strongly disagree  B. Disagree  C. Undecided  D. Agree  E. Strongly agree

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Comments and suggestions for improvements of technical features of the software:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
## B. Pedagogical Evaluation of the Software

### Pedagogical feature of software

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</tr>
</thead>
<tbody>
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<td>16. Through the use of this application, learning mathematics concepts could be more enjoyable, engaging and motivating for children than when using other resources.</td>
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<td>17. Through the use of this application, the teacher could explain and demonstrate mathematical concepts.</td>
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</tr>
<tr>
<td>26. The software allows for student reflection.</td>
<td></td>
</tr>
<tr>
<td>27. It would be easy for students to create a simple maths concept stories through the use of this application.</td>
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<td>28. Through the use of this application, students’ critical thinking and analysis could be encouraged.</td>
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<td></td>
</tr>
</tbody>
</table>

Comments and suggestions for improvements:
C. General comments

36. If you could choose, would you use this software and the teaching aids in your classroom?

☐ Yes  ☐ No

Comments: Why/Why not?

37. Would you use this interactive book and teaching aids instead of the traditional book in your classroom?

☐ Yes  ☐ No

Comments: Why/Why not?

38. In your opinion, this software was a step forward from the first software (One is a Snail, Ten is a Crab)?

☐ Yes  ☐ No

Comments: Why/Why not?

Please describe what you did like /not like about using this software?

Approval to conduct this research has been provided by the University of Western Australia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time. In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Research Ethics Office at the University of Western Australia on (08) 6488 3703 or by emailing to hreo-research@uwa.edu.au. All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.
## MY MATHS STORY SOFTWARE AND TEACHING AIDS
### (OBSERVATION FORM)

#### A. Pre-observation

<table>
<thead>
<tr>
<th>Date:</th>
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</thead>
<tbody>
<tr>
<td>School:</td>
</tr>
<tr>
<td>Kind of school:</td>
</tr>
<tr>
<td>public</td>
</tr>
<tr>
<td>Teacher:</td>
</tr>
<tr>
<td>Grade:</td>
</tr>
<tr>
<td>Class size:</td>
</tr>
<tr>
<td>regular classroom</td>
</tr>
<tr>
<td>Number of boys:</td>
</tr>
<tr>
<td>Number of girls:</td>
</tr>
</tbody>
</table>

**Brief description of lesson:**

**Goal of instruction:**

**Role of software and associated teaching aids in teaching and learning:**

**Other information:**

**Observer note:**
B. Observation and Recording (watch and record)

Type of available technology/computer in classroom or lab:
- ☐ Smart board
- ☐ Desktop computer
- ☐ Laptop

Type of application:
- ☐ Software
- ☐ Worksheet
- ☐ Group project

Class organization:
- ☐ Teacher uses the application for demonstrating and explaining mathematical concepts
- ☐ Students use the application individually (drill and practice)
- ☐ Students use the application in pairs
- ☐ Groups of students use the application (average size.................)
- ☐ Students presentations (students are presenting to the class, individually or in small groups)
- ☐ Other (specify.................................................................)

Observer note for technical and pedagogical evaluation:
C. Post- Observation

Did the teacher use the mathematics multimedia application as planned?

Briefly describe the lesson that was taught through the application.

How did the application assist the teacher to demonstrate the mathematical topic?

Were there obstacles to implementing the lesson plan in the classroom? Describe the obstacles.

Other relevant information:

Observer note:
I would give the software _____ out of 10 😊

I like the software because ______________________________________________________________

____________________________________________________________________________________

It helps me learn maths because ________________________________________________________

____________________________________________________________________________________
### Appendix E: Qualitative codebook

<table>
<thead>
<tr>
<th>Code Name</th>
<th>Definition</th>
<th>Sample of Key Words</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learnability</strong></td>
<td>The system is easy to learn so that the user can rapidly start getting some work done with the system.</td>
<td>ease of learning, learnable, easy to learn the system, easy to find, easily learnable, easy interaction, learn the software easily, finish tasks easily, easy to accomplish a task, straightforward</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>The system is efficient to use, so that once the user has learned the system, a high level of productivity is possible.</td>
<td>easy to navigate, easy to find, easy to use, easy to add graphic, easy to switch from one element to another element, moving easily and fast from one page to another page, doing a task quickly, productivity,</td>
</tr>
<tr>
<td><strong>Memorability</strong></td>
<td>The system is easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything again.</td>
<td>remember icons, remember button, simple, remember function, remember multimedia element</td>
</tr>
<tr>
<td><strong>Errors</strong></td>
<td>The system has a low error rate, system prevents users errors and recovers well from possible errors made. Catastrophic errors should not exist.</td>
<td>solve system problem, solve functional problem, fix problem, fix error, minor error, major error, resolve error independently, recover from error</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>The system is pleasant to use, for example users are subjectively satisfied when using; they like it.</td>
<td>enjoyable to use, like to use it again, back using software often, enjoy to working, like it, children enjoy it, children like to work on the system, pleasant to use, very happy, satisfy, please to use</td>
</tr>
<tr>
<td><strong>Remembering</strong></td>
<td>Recall previous learned information.</td>
<td>defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognises, reproduces, selects, states.</td>
</tr>
<tr>
<td><strong>Understanding</strong></td>
<td>Comprehending the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.</td>
<td>comprehends, converts, defends, distinguishes, estimates, explains, extends, generalises, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarises, translates.</td>
</tr>
<tr>
<td><strong>Applying</strong></td>
<td>Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the classroom into novel situations in the work place.</td>
<td>applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, shows, solves, uses.</td>
</tr>
<tr>
<td><strong>Analysing</strong></td>
<td>Separates material or concepts into component parts so that its organisational structure may be understood. Distinguishes between facts and inferences.</td>
<td>analyses, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.</td>
</tr>
<tr>
<td><strong>Evaluating</strong></td>
<td>Make judgments about the value of ideas or materials.</td>
<td>appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarises, supports.</td>
</tr>
<tr>
<td><strong>Creating</strong></td>
<td>Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.</td>
<td>categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organises, plans, rearranges, reconstructs, relates, reorganises, revises, rewrites, summarises,</td>
</tr>
<tr>
<td><strong>Storytelling</strong></td>
<td>Using children’s literature to connect children to the abstract and symbolic language of mathematics</td>
<td>children literature, plot, setting, characters, hero, theme, style, characters, children literature, storybook, real life story</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td>Users willingness, need, desire and compulsion to participate in, and be successful in the teaching and learning process.</td>
<td>motivate children, appealing, happy to do a task, willing to do a task, desire, like to do more, interested, inspire, encourage, enthusiasm</td>
</tr>
<tr>
<td><strong>Engagement</strong></td>
<td>The intensity and emotional quality of users involvement in initiating and carrying out learning activities.</td>
<td>engage in activity, involvement, involve in task, engagement, behavioral, paying attention, involvement in learning activities, positive emotional toward doing task, responding to teacher</td>
</tr>
<tr>
<td><strong>Multiple Representations</strong></td>
<td>Providing the same information in more than one form.</td>
<td>multimodal presentation, presenting same information in more than one form, demonstrate the same concepts, ability to present and demonstrate information in more than one medium, support specific kind of learning, combinations of text and audio, still and motion visuals, process specific information, learners preferred type of learning, variety of delivery format</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>Users have a range of options from which to choose with respect to key learning dimensions.</td>
<td>open ended, manipulate for different levels, using different ICT tools, range of options, choices available to both learners and teachers, create adaptable and differentiated instruction, addresses different learning styles, options available to learners, control over teaching and learning, variety of learning modes and interactions, flexibility in location, flexibility in program, flexibility in types of interactions, flexibility in forms of</td>
</tr>
<tr>
<td><strong>Feedback</strong></td>
<td>Teachers’ responses to learners answer. It can help teachers to identify errors and become aware of misconceptions and areas that need to be consolidated.</td>
<td>respond to a answer, respond to solution, finding different way, asking how, asking why, asking what happen, information from conversation, assessment, opinion, responses</td>
</tr>
<tr>
<td><strong>Collaboration</strong></td>
<td>Student work in pair or group to learn a concept. For example, students tackle a mathematics problem and learn from their peers and build on their skills.</td>
<td>teamwork, group project, work as a team, work in pair, work together, solve a problem together, association, involve in one task, share, exchange and discuss ideas, learn from peers, learn from other, collaborative learning</td>
</tr>
<tr>
<td><strong>Curriculum alignment</strong></td>
<td>Australian Curriculum including ICT, Mathematics, English, Science, History and Culture strands.</td>
<td>number and algebra, number and place value, fractions and decimals, money and financial, patterns and algebra, measurement and geometry, clock, time, units of measurement</td>
</tr>
</tbody>
</table>
Appendix F: Sample letter of invitation and a consent form

A computer-assisted framework based on the Bloom-Anderson taxonomy for teaching mathematics in early primary years

Dear [Teacher]

The twenty-first century has so far seen rapid developments in the domains of technology. The use of Information and Communication Technologies (ICT) has become very common in all aspects of our daily life. Within education, the development of new Information and Communications Technologies has resulted in significant changes in the way that teachers teach and children learn in school. As you are well aware, the new Australian Curriculum includes a strong focus on ICT skills in individual learning areas. In regards to the teaching of mathematics, providing children with mathematical skills are essential and it is important for teachers to learn how to make best use of new technologies when they become available.

The purpose of this research is to design a framework for effective use of ICT in mathematics education for lower primary school children. This framework will be based on current pedagogical views of mathematics education. An outcome of the research will be the development of appropriate software and multimedia content based on the framework. The software and multimedia documents will be used for teaching primary school students for approximately one school term.

You have been identified as someone who is engaging in innovative practice in this area. We would like to invite you to take part in the study during Term ----- of -----. The data collected in this study will be used in a report that will provide information about how teachers and students can use appropriate computer based educational application in classroom to enhance mathematical achievement. The principal at your school has given consent for you to participate if you choose to.

What does participation in the research project involve

- You will be invited to allow researcher from UWA to observe your use of computer application when teaching maths to the children in your class.
- You will be invited to enter into discussions (a short semi-structured interview) with the researcher about the successes and challenges you experience in using these application in your classroom.
- You may be asked to allow researcher to take photo and video record your teaching while using the developed mathematics application.
- You will assist in the distribution and collection of permission forms from parents and students.

What you need to know about the research process

- Participants can withdraw at any time.
- Participant contributions can be destroyed or discussed with the researcher as appropriate. However, if the project has already been published at the time a participant decides to withdraw, their contribution cannot be removed from the publication.
- Researcher working in the school has undertaken a National Criminal History Record and a Working with Children Check.
Mathematics Education - UWA Research Project - Information and Consent Letters

- This research has been approved by the ethics committees at the University of Western Australia and Department of Education.
- No information on individual teachers, students or schools will be published in the report or any other publications resulting from this study.
- The data from this project will be stored securely at The University of Western Australia and will only be accessed by the research team. The data will be stored for a minimum period of 5 years, after which it will be destroyed.

If you have any questions or require more information about the research project please do not hesitate to contact researcher Nasrin Moradmand on 6488 2238 or email: nasrin.moradmand@hrs.uwa.edu.au or her supervisor, Professor Amitava Datta on 6488 3449 or email datta@csse.uwa.edu.au. When you have had time to read this information sheet, please return the attached signed consent forms and return it to me by (Date). This project information letter is for you to keep.

Yours sincerely

Nasrin Moradmand, PhD candidate
A computer-assisted framework based on the Bloom-Anderson taxonomy for teaching mathematics in early primary years

Teacher’s Informed Consent

- I have read the information letter, which explains the research project, and any questions I have asked have been answered to my satisfaction.
- I understand that participation in this project is entirely voluntary.
- I understand that I may withdraw my permission at any time without affecting my relationship with my school.
- I understand that all information provided is treated as strictly confidential and will not be released by the researcher. The only exception to this principle of confidentiality is if a court subpoenas documentation or directs other legal means. I have been advised as to what data is being collected, what the purpose is, and what will be done with the data upon completion of the research.
- I agree that research data gathered for the study may be published, as a report provided my name or other identifying information is not used.

Teacher’s Name: ________________________________

Teacher’s Signature: ____________________________

School: ________________________________

Date: ________________________________

Approval to conduct this research has been provided by the University of Western Australia, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time.

In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Research Ethics Office at the University of Western Australia on (08) 6488 3703 or by emailing to hreo-research@uwa.edu.au.

All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.
About this software

The My Maths Story application is multimedia educational software, based on "ONE IS A SNAIL, TEN IS A CRAB: A COUNTING BY FEET BOOK" by April Pulley Sayre & Jeff Sayre. This educational software is fundamentally an Interactive Storybook, aiming to assist teaching mathematics concept in lower primary schools classroom.

The My Maths Story application is based on current pedagogical views of mathematics education and planning and aims to make learning more fun and motivational for students, help with deep understanding of concepts using multiple representations, and thus assist children remember and apply the material. My Maths Story aims to help teachers provide a thorough educational experience that incorporates many proven learning concepts into the curriculum.

Who can use this software?

Teachers, students, education experts and parents can benefit from using this software.

Support

For more information, help, feedback, suggestions or general inquiries about this application, please contact, Nasrin Moradmand, Researcher/Software designer and developer on +61402604180 or nasrin.moradmand@grs.uwa.edu.au.

How to use this software?

Since the target audience for this software is early primary students, and we cannot assume a high level of computer skills among young children, the application is simple and easy to use and should be intuitive in many ways. For brief instructions, see below:
Book Cover

This page contains the cover of the book and publisher permission.

1. **Help**: this icon navigates user to the user guide (this manual).
2. **Publisher permission**
3. **Start story**: by click on this icon, story will be started.
This page can help the user to navigate to the different parts of the interactive storybook. It helps the user to find, and shows the order of, different parts of the storybook.

1. **Previous page**: by clicking on this icon, the user navigates to the previous page.
2. **Background sound on**
3. **Background sound off**
4. **Next page**: by clicking on this icon, the user navigates to the next page.
5. **Table of Content**: by clicking on the individual hyperlink, the user navigates to the different parts of the storybook.

---
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Inside pages

1. **Homepage:** by clicking on this icon the user is taken back to the Table of Contents page.

2. **Characters:** by clicking on a character, dragging and dropping it to the stage, the user can add it to the story.
   - **Note:** other characters of the book (a person, dog, insect, spider and crab) will be added to this section as story continues.

3. **Number:** by clicking on this icon, animated numeral writing will be activated, for example number 1, 2, 3...10.
   - **Note:** Animation of numeral writing is based on the Victorian Cursive writing style.

4. **Text:** by click on this icon, the alphabetic writing animation of a number appears, for example ‘one’, ‘two’, ‘three’, …‘ten’
   - **Note:** Animation of alphabetic writing is based on the Victorian Cursive writing style.

5. **Arrow:** click, drag and drop this icon to show characters’ feet.

6. **Sound:** by clicking on this icon a sound is made. This will help learner to count by sound (hearing).

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Blackboard: By clicking on this icon, a text box (like a blackboard) appears on the stage, which the user can type in.

Story reader: by clicking on this icon, the software will read the book aloud page by page.

Clean and Trash: by clicking on this icon, the working stage will be cleaned and the page will be reloaded.
Also, this icon can be used for trashing characters. The user can delete objects by dragging and dropping them onto this icon (very useful tool for teaching subtraction).

Inside pages: After number 10

In the “One is a snail, Ten is a crab” book, after counting to 10, the book focuses on skip counting by 10s. In the interactive book, an extra page has added between the two tens (between numbers 10 and 20, numbers 20 and 30…numbers 90 and 100). Here, users are able to design and create their own stories for the missing numbers, such as numbers 11, 12, 13…19 (between numbers 10 and 20) or numbers 61, 62,63…69 (between numbers 60 and 70).

Pen: by clicking on this icon, the user can write and draw, for example writing number 12 or drawing a new character.
Bibliographic details of book:

User Guide

About this software

The Count on me! application is a multimedia educational software as part of “My Maths Story” project. It is based on “COUNT ON ME! A MATHEMATICS ADVENTURE STORY BOOK” by Nasrin Moradmand. This educational software is fundamentally an Interactive Storybook, aiming to assist teaching and learning mathematics concepts in the lower primary schools classroom.

The My Maths Story application is based on current pedagogical views of mathematics education and aims to make learning more fun and help students in deep understanding of mathematics concepts using multiple representations, and thus assist children remember and apply the material.

The software aims to help teachers to provide a thorough educational experience that incorporates many proven learning concepts into the curriculum. The software is based on a strong educational framework and Australian new curriculums. It can be used for addressing content across the four content in Number and Algebra strand (Number and place value, Money and financial mathematics, Fractions and decimals, Patterns and algebra) and Measurement and Geometry strand (Using units of measurement, Shape, Location and transformation).

Who can use this software?

Teachers, students, education experts and parents can benefit from using this software.

Support

For more information, help, feedback, suggestion or general inquiry about this application, please contact, Nasrin Moradmand, Researcher/Software designer and developer on +61402604180 or nasrin.moradmand@grs.uwa.edu.au.

How to use this software?

Since the target audience for this software is early primary students, and we cannot assume a high level of computer skills among young children, the application is simple and easy to use and should be intuitive in many ways. For brief instructions, see below:
This page contains the cover of the book and publisher permission.

1. Help: this icon navigates user to the user guide (this manual).
2. Publisher permission
3. Start story: by click on this icon, story will be started.
This page can help the user to navigate to the different parts of the interactive storybook. It helps the user to find and shows the order of different parts of the storybook.

1. **Previous page**: navigates to the previous page.
2. **Next page**: navigates to the next page.
3. **Table of Content**: individual hyperlink directs to the different parts of the storybook.
Inside pages

1. **Homepage**: clicking on this icon take user back to the Table of Contents page.
2. **Story reader**: the software reads the book aloud page by page and show the story text (3) and animation.
3. **Story text**: story text will appear by clicking on the **Story reader** icon.
4. **Replay**: the software will replay the story.
5. **Clean and Trash**: by clicking on this icon, the working stage will be cleaned and the page will be reloaded. This icon can be used for trashing characters. User can delete objects by dragging and dropping them onto this icon (very useful tool for teaching subtraction).
Interactive Story Book: User Guide

① **Eraser**: erase hand-drawn lines (by Pen button).

② **Pen**: by select and mouse down, user can write and draw, for example writing numbers, drawing line or a new character.

③ **Map**: by clicking on this, map of the village appears and user can show positions and pathways.

④ **Clock**: by rollovering to the hour and minute hands and turning in clockwise, the clock time will change.
In the “Count on me!” interactive book, after introducing the village and story’s characters, the story focused on individual mathematics concept strands. For example in the farm, the story highlighted the use of **Number and place value**; in the shop attention is on the **Money and financial** in mathematics. **Patterns and algebra/Shapes** concepts are emphasised in the carpentry shop setting and **Fractions and decimals** in the bakery shop. This software, also considered the concept of **Measurement and Geometry** strand by introducing village map (Location and transformation) and Clock (Using units of measurement and relationship between units).

1. **Numbers**: user can drag and drop individual number to the stage.
2. **Maths symbols**: user can drag and drop the basic maths symbols (+, -, x, =, ) to the stage.
3. **Number word**: user can drag and drop the numeral writing to the stage (Victorian Cursive writing style).
4. **Blackboard**: By clicking on this icon, a text box (like a blackboard) appears on the stage. User can type in and move this text box.
5. **Farm elements**: user can drag and drop all farm elements (vegetables, fruits, farm animals) to the stage.
6. **Work area**: or work stage, user can drag and drop all elements to this area as well as write, draw and erase.
1. **Money sign**: user can drag and drop Australian money sign ($ and C) to the stage.

2. **Australian money coins**: user can drag and drop 5C, 10C, 20C, 50C, $1, $2 coins to the work area.

3. **Australian money notes**: user can drag and drop $5, $10, $20, $50, $100 notes to the work area.

4. **Shopping list**: user can click and then type a shopping list.

5. **Shopping elements**: user can drag and drop all the shopping elements (grocery items) to the stage.

6. **Work area**: or work stage, user can drag and drop all elements to this area.
1. **Transforming tool- scale up**: by drag and rollover an object (shape) over this icon, the object size will enlarge.

2. **Shapes**: user can drag and drop different shapes to the stage.

3. **Grid**: by clicking on this icon, a grid map appears.

4. **Colours**: user can drag and rollover an object (shape) on different colours to change the shape’s colour.

5. **Transforming tool- scale down**: by drag and rollover an object (shape) over this icon, the object size will reduce.

6. **Work area**: or work stage, user can drag and drop all elements to this area as well as write, draw and erase.
1. **Bakery elements:** user can drag and drop bakery elements (sweet and savouries) to the stage.

2. **Slice tool:** by click on this icon, number of slice buttons will appear (3) and user can drag a pizza to any of these icons to cut the pizza in different slices such as 2 slices, 3 slices, ...etc.

3. **Different Slice tool:** each icon will cut a pizza to proper slices.

4. **Work area:** or work stag, user can drag and drop all elements to this area as well as write, draw and erase.
Mathematics

Foundation Year

Foundation Year Content Descriptions

<table>
<thead>
<tr>
<th>Number and Algebra</th>
<th>Measurement and Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number and place value</td>
<td>Using units of measurement</td>
</tr>
<tr>
<td>Establish understanding of the language and processes of counting by naming numbers in sequences, initially to and from 20, moving from any starting point (ACMNA001)</td>
<td>Use direct and indirect comparisons to decide which is longer, heavier or holds more, and explain reasoning in everyday language (ACMMG006)</td>
</tr>
<tr>
<td>Connect number names, numerals and quantities, including zero, initially up to 10 and then beyond (ACMNA002)</td>
<td>Compare and order the duration of events using the everyday language of time (ACMMG007)</td>
</tr>
<tr>
<td>Subitise small collections of objects (ACMNA003)</td>
<td>Connect days of the week to familiar events and actions (ACMMG008)</td>
</tr>
<tr>
<td>Compare, order and make correspondences between collections, initially to 20, and explain reasoning (ACMNA289)</td>
<td>Shape</td>
</tr>
<tr>
<td>Represent practical situations to model addition and sharing (ACMNA004)</td>
<td>Sort, describe and name familiar two-dimensional shapes and three-dimensional objects in the environment (ACMMG009)</td>
</tr>
<tr>
<td>Patterns and algebra</td>
<td>Location and transformation</td>
</tr>
<tr>
<td>Sort and classify familiar objects and explain the basis for these classifications. Copy, continue and create patterns with objects and drawings (ACMNA005)</td>
<td>Describe position and movement (ACMMG010)</td>
</tr>
</tbody>
</table>

Year 1

Year 1 Level Description

The proficiency strands Understanding, Fluency, Problem Solving and Reasoning are an integral part of mathematics content across the three content strands: Number and Algebra, Measurement and Geometry, and Statistics and Probability. The proficiencies reinforce the significance of working mathematically within the content and describe how the content is explored or developed. They provide the language to build in the developmental aspects of the learning of mathematics.

At this year level: Understanding includes connecting names, numerals and quantities, and partitioning numbers in various ways
Fluency includes counting number in sequences readily forward and backwards, locating numbers on a line, and naming the days of the week.

Problem Solving includes using materials to model authentic problems, giving and receiving directions to unfamiliar places, and using familiar counting sequences to solve unfamiliar problems and discussing the reasonableness of the answer.

Reasoning includes explaining direct and indirect comparisons of length using uniform informal units, justifying representations of data, and explaining patterns that have been created.

### Year 1 Content Descriptions

#### Number and Algebra

- **Number and place value**
  - Develop confidence with number sequences to and from 100 by ones from any starting point. Skip count by twos, fives and tens starting from zero (ACMNA012).
  - Recognise, model, read, write and order numbers to at least 100. Locate these numbers on a number line (ACMNA013).
  - Count collections to 100 by partitioning numbers using place value (ACMNA014).
  - Represent and solve simple addition and subtraction problems using a range of strategies including counting on, partitioning and rearranging parts (ACMNA015).

- **Fractions and decimals**
  - Recognise and describe one-half as one of two equal parts of a whole. (ACMNA016)

- **Money and financial mathematics**
  - Recognise, describe and order Australian coins according to their value (ACMNA017).

- **Patterns and algebra**
  - Investigate and describe number patterns formed by skip counting and patterns with objects (ACMNA018).

#### Measurement and Geometry

- **Using units of measurement**
  - Measure and compare the lengths and capacities of pairs of objects using uniform informal units (ACMMG019).
  - Tell time to the half-hour (ACMMG020).
  - Describe duration using months, weeks, days and hours (ACMMG021).

- **Shape**
  - Recognise and classify familiar two-dimensional shapes and three-dimensional objects using obvious features (ACMMG022).

- **Location and transformation**
  - Give and follow directions to familiar locations (ACMMG023).

---

**Year 2**

**Year 2 Level Description**

The proficiency strands Understanding, Fluency, Problem Solving and Reasoning are an integral part of mathematics content across the three content strands: Number and Algebra, Measurement and Geometry, and Statistics and Probability. The proficiencies reinforce the significance of working mathematically within the content and describe how the content is explored or developed. They provide the language to build in the developmental aspects of the learning of mathematics.

At this year level:

Understanding includes connecting number calculations with counting sequences, partitioning and combining numbers flexibly, identifying and
### Number and Algebra

**Number and place value**
- Investigate number sequences, initially those increasing and decreasing by twos, threes, fives and ten from any starting point, then moving to other sequences. (ACMNA026)
- Recognise, model, represent and order numbers to at least 1000 (ACMNA027)
- Group, partition and rearrange collections up to 1000 in hundreds, tens and ones to facilitate more efficient counting (ACMNA028)
- Explore the connection between addition and subtraction (ACMNA029)
- Solve simple addition and subtraction problems using a range of efficient mental and written strategies (ACMNA030)
- Recognise and represent multiplication as repeated addition, groups and arrays (ACMNA031)
- Recognise and represent division as grouping into equal sets and solve simple problems using these representations (ACMNA032)

### Fractions and decimals
- Recognise and interpret common uses of halves, quarters and eighths of shapes and collections (ACMNA033)

### Money and financial mathematics
- Count and order small collections of Australian coins and notes according to their value (ACMNA034)

### Patterns and algebra
- Describe patterns with numbers and identify missing elements

### Measurement and Geometry

**Using units of measurement**
- Compare and order several shapes and objects based on length, area, volume and capacity using appropriate uniform informal units (ACMMG037)
- Compare masses of objects using balance scales (ACMMG038)
- Tell time to the quarter-hour, using the language of ‘past’ and ‘to’ (ACMMG039)
- Name and order months and seasons (ACMMG040)
- Use a calendar to identify the date and determine the number of days in each month (ACMMG041)

**Shape**
- Describe and draw two-dimensional shapes, with and without digital technologies (ACMMG042)
- Describe the features of three-dimensional objects (ACMMG043)

**Location and transformation**
- Interpret simple maps of familiar locations and identify the relative positions of key features (ACMMG044)
- Investigate the effect of one-step slides and flips with and without digital technologies (ACMMG045)
- Identify and describe half and quarter turns (ACMMG046)
Solve problems by using number sentences for addition or subtraction (ACMNA036)

Year 3

Year 3 Level Description
The proficiency strands Understanding, Fluency, Problem Solving and Reasoning are an integral part of mathematics content across the three content strands: Number and Algebra, Measurement and Geometry, and Statistics and Probability. The proficiencies reinforce the significance of working mathematically within the content and describe how the content is explored or developed. They provide the language to build in the developmental aspects of the learning of mathematics.

At this year level:
Understanding includes connecting number representations with number sequences, partitioning and combining numbers flexibly, representing unit fractions, using appropriate language to communicate times, and identifying environmental symmetry.

Fluency includes recalling multiplication facts, using familiar metric units to order and compare objects, identifying and describing outcomes of chance experiments, interpreting maps and communicating positions.

Problem Solving includes formulating and modelling authentic situations involving planning methods of data collection and representation, making models of three-dimensional objects and using number properties to continue number patterns.

Reasoning includes using generalising from number properties and results of calculations, comparing angles, creating and interpreting variations in the results of data collections and data displays.

Year 3 Content Descriptions

### Number and Algebra

#### Number and place value

- Investigate the conditions required for a number to be odd or even and identify odd and even numbers (ACMNA051)
- Recognise, model, represent and order numbers to at least 10 000 (ACMNA052)
- Apply place value to partition, rearrange and regroup numbers to at least 10 000 to assist calculations and solve problems (ACMNA053)

#### Number operations

- Recognise and explain the connection between addition and subtraction (ACMNA054)
- Recall addition facts for single-digit numbers and related subtraction facts to develop increasingly efficient mental strategies for calculation (ACMNA055)
- Recall multiplication facts of two, three, five and ten and related division facts (ACMNA056)

#### Number and operations

- Represent and solve problems involving multiplication using efficient mental and written strategies and appropriate digital tools.

### Measurement and Geometry

#### Using units of measurement

- Measure, order and compare objects using familiar metric units of length, mass and capacity (ACMMG061)
- Tell time to the minute and investigate the relationship between units of time (ACMMG062)

#### Shape

- Make models of three-dimensional objects and describe key features (ACMMG063)

#### Location and transformation

- Create and interpret simple grid maps to show position and pathways (ACMMG065)

#### Geometric reasoning

- Identify symmetry in the environment (ACMMG066)
- Identify angles as measures of turn and compare angle sizes in everyday situations (ACMMG064)
The Australian Curriculum v6.0 Mathematics Foundation to Year 10 Curriculum by rows

<table>
<thead>
<tr>
<th>Technologies (ACMNA057)</th>
</tr>
</thead>
</table>

### Fractions and decimals

Model and represent unit fractions including 1/2, 1/4, 1/3, 1/5 and their multiples to a complete whole (ACMNA058)

### Money and financial mathematics

Represent money values in multiple ways and count the change required for simple transactions to the nearest five cents (ACMNA059)

### Patterns and algebra

Describe, continue, and create number patterns resulting from performing addition or subtraction (ACMNA060)

---

**Year 4**

**Year 4 Level Description**

The proficiency strands Understanding, Fluency, Problem Solving and Reasoning are an integral part of mathematics content across the three content strands: Number and Algebra, Measurement and Geometry, and Statistics and Probability. The proficiencies reinforce the significance of working mathematically within the content and describe how the content is explored or developed. They provide the language to build in the developmental aspects of the learning of mathematics.

At this year level:

**Understanding** includes making connections between representations of numbers, partitioning and combining numbers flexibly, extending place value to decimals, using appropriate language to communicate times, and describing properties of symmetrical shapes.

**Fluency** includes recalling multiplication tables, communicating sequences of simple fractions, using instruments to measure accurately, creating patterns with shapes and their transformations, and collecting and recording data.

**Problem Solving** includes formulating, modelling and recording authentic situations involving operations, comparing large numbers with each other, comparing time durations, and using properties of numbers to continue patterns.

**Reasoning** includes using generalising from number properties and results of calculations, deriving strategies for unfamiliar multiplication and division tasks, comparing angles, communicating information using graphical displays and evaluating the appropriateness of different displays.

**Year 4 Content Descriptions**

<table>
<thead>
<tr>
<th>Number and Algebra</th>
<th>Measurement and Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number and place value</strong></td>
<td><strong>Using units of measurement</strong></td>
</tr>
<tr>
<td>Investigate and use the properties of odd and even numbers (ACMNA071)</td>
<td>Use scaled instruments to measure and compare lengths, masses, capacities and temperatures (ACMMG084)</td>
</tr>
<tr>
<td>Recognise, represent and order numbers to at least tens of thousands (ACMNA072)</td>
<td>Compare objects using familiar metric units of area and volume (ACMMG290)</td>
</tr>
<tr>
<td>Apply place value to partition, rearrange and regroup numbers to at least tens of thousands to assist calculations and solve problems (ACMNA073)</td>
<td>Convert between units of time (ACMMG085)</td>
</tr>
<tr>
<td>Topic</td>
<td>Subtopic</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
</tr>
<tr>
<td>Fractions and decimals</td>
<td>Investigate equivalent fractions used in contexts (ACMNA077)</td>
</tr>
<tr>
<td></td>
<td>Count by quarters halves and thirds, including with mixed numerals. Locate and represent these fractions on a number line (ACMNA078)</td>
</tr>
<tr>
<td></td>
<td>Recognise that the place value system can be extended to tenths and hundredths. Make connections between fractions and decimal notation (ACMNA079)</td>
</tr>
<tr>
<td>Money and financial mathematics</td>
<td>Solve problems involving purchases and the calculation of change to the nearest five cents with and without digital technologies (ACMNA080)</td>
</tr>
<tr>
<td>Patterns and algebra</td>
<td>Explore and describe number patterns resulting from performing multiplication (ACMNA081)</td>
</tr>
<tr>
<td></td>
<td>Solve word problems by using number sentences involving multiplication or division where there is no remainder (ACMNA082)</td>
</tr>
<tr>
<td></td>
<td>Use equivalent number sentences involving addition and subtraction to find unknown quantities (ACMNA083)</td>
</tr>
<tr>
<td>Use am and pm notation and solve simple time problems</td>
<td>Use am and pm notation and solve simple time problems (ACMMG086)</td>
</tr>
<tr>
<td>Shape</td>
<td>Compare the areas of regular and irregular shapes by informal means (ACMMG087)</td>
</tr>
<tr>
<td></td>
<td>Compare and describe two dimensional shapes that result from combining and splitting common shapes, with and without the use of digital technologies (ACMMG088)</td>
</tr>
<tr>
<td>Location and transformation</td>
<td>Use simple scales, legends and directions to interpret information contained in basic maps (ACMMG090)</td>
</tr>
<tr>
<td></td>
<td>Create symmetrical patterns, pictures and shapes with and without digital technologies (ACMMG091)</td>
</tr>
<tr>
<td>Geometric reasoning</td>
<td>Compare angles and classify them as equal to, greater than or less than a right angle (ACMMG089)</td>
</tr>
</tbody>
</table>
“for Sana and all the beautiful children who love to learn”

Nasrin
November 2012
I am Hannah. I live at Banksia Village in Western Australia.

It is called Banksia Village because many banksia plants grow here. Banksia Village has a farm, bakery, carpentry and shop.
I love going around the village on my bike and saying “Hello!” to people.
This is Banksia farm. I live with my mum and dad on the farm. We have a big farm with a rooster, four hens and their chicks.

We grow vegetables and fruits on our farm. Every day, my mum and dad work hard on the farm.
This is Monsieur Moreau. Monsieur Moreau works in the Banksia bakery. He bakes amazing desserts and cakes. My mum makes jam for Monsieur Moreau and he uses it in his cakes and biscuits.

“Hello, Monsieur Moreau.”

“Bonjour, Hannah,” says Monsieur Moreau.

“Could you please tell your mum I need seven jars of jam – two jars of strawberry jam, one jar of cherry jam and the rest raspberry jam,” says Monsieur Moreau.

“Yes, I will.”
This is the carpenter, Tony. Carpenter Tony works at the Banksia carpentry. He is very good at making things and painting and varnishing them. He made us four chairs and a table and now he is fixing our farm fence.

“Hello, Carpenter Tony.”

“Oh, hello Hannah. I am going to fix your farm fence tomorrow,” says Tony.

“Great, I will let my mum know.”

“Thanks,” says Tony.
This is the Banksia shop. Sarah works here. She is selling some of our farm vegetables, herbs, fruits and eggs. I can see some of them in the shop, can you?

“Hello, Sarah.”

“Hello, Hannah,” replies Sarah.

“Do you need anything from our farm for your shop?” I ask.

“Yes, could you please tell your dad, I need two dozen eggs, nine bunches of basil and ten capsicums - three red, two yellow and the rest green ones,” says Sarah.

“Yes, sure. I will let him know.”

“Thank you, Hannah,” says Sarah.
This is the postman, Tim. He brings mails from around the world to us.

“Hello, Postman Tim.”

“Hello, Hannah,” says Postman Tim.

“Any letters for me today?”

“Yes, you have a letter. Here it is …” says Postman Tim.

“Oh yes, a letter from Grandma, my mum will be very happy to see this letter.”
Here is my home.
“Hi, mum”
“Hello, Hannah. How was your bike ride?”, asks mum.
“It was good, thanks. I saw Monsieur Moreau. He told me he needs seven jars of jam- two jars of strawberry jam, one jar of cherry jam and the rest raspberry jam. Carpenter Tony is going to fix our farm fence tomorrow and Sarah needs two dozen eggs, nine bunches of basil and ten capsicums - three red, two yellow and the rest green, for her shop”.
“Thanks for remembering all of these things,” says mum. “Any letters from Postman Tim?”
“Yes, a letter from Grandma.”
My mum is reading Grandma’s letter very quietly.
“Is everything alright, mummy?”
“Grandma is not well and wants me to visit her,” mum tells me.
“Oh, no.”
“But I have so much work to do! Dad needs help on the farm to pick some vegetables for Sarah’s shop. I need to visit Carpenter Tony about fixing our farm fence, and I need to drop some jars of jam to Monsieur Moreau, and choose some cakes …what should I do?”, asks mum.
“I will help you, mum, count on me! You should visit Grandma today, she needs you.”
“Thanks, Hannah. I think, I will write you a list of things so you know what to do,” says mum.
Mum left the village to visit Grandma. Mum wrote me a list of things to do. I know I am going to have a big day today as I have to help four people.

First, I need to help dad on the farm.
“Good morning, dad.”

“Good morning, Hannah. Ready for the big day?” asks dad.

“Yes, I am. Count on me! First, I need to collect two dozen eggs. I know that one dozen is 12 eggs, so two groups of 12 is 24 ... so I need 24 eggs. Here are 2, 4, 6, 8, 10, 12 eggs.”

= 12
"Now, I need another dozen. I will do my counting faster this time ... how about 4, 8 and 12 eggs?"

= 12

"Ok, I have collected my two dozen eggs."

"The next thing I need is nine bunches of basil. Here are 3, 6 and 9 of them. Done!"

= 9

"Finally, I need ten capsicums, three of them red ... 1, 2, 3. Two yellow, here they are...

and the rest are green ones? How many green capsicums do I need?
I have my 3 red capsicums and 2 yellow capsicums, so it makes 5 capsicums. But I need 10 capsicums altogether. I already have 5 of them, so that means..."

and ？ = 10

"...I need another 5 to make 10. Hooray, I worked it out!"
Can you think of another way of doing this?

Now I am ready to go to Sarah's shop.
“Hi Sarah, here are two dozen eggs, nine bunches of basil and ten capsicums from the farm.”

“Thank you Hannah, I will pay $4 for each dozen eggs,” says Sarah.

“$4  $4

“We have two dozen eggs, and each dozen is $4. So $4 and $4 is $8.”
"$2 for each bunch of basil," says Sarah.  
"We have 9 bunches. 9 times $2 equals $18."

"Great, you are good at numbers, Hannah. Now, for these capsicums - red and green capsicums are $1 each and I will pay $1 for every two yellow capsicums," says Sarah.

"We have 3 red capsicums and 5 green capsicums, so 3 and 5 make 8. 8 times $1 equals $8. $8 for red and green capsicums. Every two yellow capsicums is $1. We just have two of them so it would be exactly $1."

"That’s right, Hannah, So, we had $8 plus $1. How much is that in total?” asks Sarah.  
“ I know... that makes $9 in total for the capsicums.”  
“Yes, that’s right. So, how much should I pay you for the eggs, basils and capsicums?” asks Sarah, smiling brightly.

“it was $8 for eggs and $18 for basil and $9 for capsicums, so that means, $8 + $18 + $9. It makes $35 in total.”

“That’s right, Hannah, Here is the $35,” says Sarah.

“Thanks, Sarah. I will give it to my dad.”

“Thanks, Hannah,” says Sarah.

Now I have to visit Carpenter Tony.
“Hello, Carpenter Tony.”

“Hello, it is good you are here, Hannah. I need your help to fix your farm fence. It’s a picket fence and some parts are missing,” says Tony.

“Sure, I will help you to find the missing parts, count on me! Tony!”
“Here we have a black picket, then a red, then a blue, then another blue, and then brown, brown, blue,…, red, black. There is a pattern! I think one blue picket is missing here.”

“... and the other missing pickets must be blue, brown and red pickets.”
“Yes, I think you are right, Hannah,” nods Tony.

“Look, there are some other parts missing, too,” says Tony.
“Yes, some diamond shapes are missing in some spots. The pattern goes, one orange, one black, another orange and another black, so it goes orange, black, orange, black, orange, black. There’s always a black diamond after an orange diamond.”

“So, we can fix it like this….”

“Thank you so much for your help, Hannah,” says Tony. Now, I have to go to the bakery shop.
"Hello, Monsieur Moreau. Here are seven jars of jam - two jars of strawberry jam, one jar of cherry jam and four jars of raspberry jam."

"Thank you, Hannah. Do you need anything from my bakery today?" asks Monsieur Moreau.
“Yes, my mum would like six cupcakes - half vanilla and the other half, chocolate ones.”
“Sure, you can choose them yourself, if you like” says Monsieur Moreau.

“I need 6 cupcakes, half vanilla, half chocolate. What is half of 6? I know two groups of 3 make 6, so that means half of 6 must be 3. So, I need to pick 3 vanilla cupcakes and 3 chocolate cupcakes.”

\[
\text{half of 6} \quad \frac{6}{2} = 3
\]

“Done!”

“Also, Hannah, I just baked a pizza. Would you like a quarter of it for your lunch today?” asks Monsieur Moreau.

“Yes, please. Thanks very much, Monsieur Moreau.”

“Here is the whole pizza. If I cut it in two parts that are the same size, each part will be half a pizza,” explains Monsieur Moreau.

\[
\frac{1}{2} \quad \text{pizza slice} \quad \frac{1}{2}
\]

“and if I halve this slice again, here I have a quarter of the whole pizza.”

\[
\frac{1}{4} \quad \text{pizza slice} \quad \frac{1}{4} \quad \frac{1}{4} \quad \frac{1}{4}
\]

“Yumm!”
On my way home...

Finally, I am on my way home. I can not wait to tell my mum and dad about my exciting day.