

The Design and Implementation of an Educational Multimedia Mathematics Software: Using ADDIE to Guide Instructional System Design

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Abstract. 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, curriculum and pedagogy, have been highlighted as main issues that can hamper the quality and relevance of existing computer-based educational applications. The study reported in this paper addressed this disconnection and lack of alignment through the development of a strong educational framework and use of an appropriate instructional system design (ISD). The components of the framework are described in this article, followed by a discussion of the process of applying the defined instructional design principles to the creation of the My Maths Story project's interactive multimedia mathematics software. The entire implementation and evaluation process of the multimedia instructional materials, which targeted the teaching and learning of mathematics in the lower primary classrooms, is also presented.

Keywords: Instructional system design, mathematics education, multimedia software, cognitive learning

Introduction

In recent years, the teaching and learning of mathematics through computer-based education applications has grown. In the primary classroom, which in Australia covers Years 1 to 6 (children aged 6 to 11), there are many opportunities for computer-based technology to be used to enhance the teaching of curriculum areas such as English and Mathematics (Lim & Oakley, 2013). However, many studies and computer-based applications that are currently used in Australia originate from the USA and, in recent years, from other countries such as the UK and India (Eng, 2005; Moradmand, Datta, & Oakley, 2013; Yelland, Australia. Dept. of Education, & Affairs, 2001). Subsequently,

educational software packages are mainly based on the curricula and preferred pedagogies of these countries.

Furthermore, 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), as well as a lack of alignment between technology, curriculum and pedagogy (Mumtaz, 2000; Robin, 2008; Yelland, Australia. Dept. of Education, & Affairs, 2001). Thus, in many cases, sourcing computer-based technology and applications to facilitate learning in a manner that is pedagogically acceptable to teachers has become an area of challenge for Australian schools.

The purpose of the study reported here was to bridge this disconnection (between theory for designing

educational computer-based applications and theory concerned with applying these educational applications to teaching in mathematics classrooms) through the use of an appropriate instructional system design (ISD). The paper consists of two main sections. It first reviews the mathematics pedagogies and a variety of pedagogical strategies in the mathematics learning area within in early primary levels of school, along with a description of the ADDIE instructional system design components. The study's educational framework, which incorporates the cognitive learning theory of the Bloom/Anderson taxonomy (2001) to shape and define computer-based instructional materials, is also presented. The second part of this paper discusses the process of applying the defined instructional design principles to the creation of the My Maths Story project's interactive multimedia mathematics software. The paper presents the implementation and evaluation process of the multimedia instructional materials for assisting in the teaching and learning of mathematics in lower primary school, based on the ADDIE framework components.

Pedagogy in mathematics

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. In the field of mathematics education for young children, inclusion of children's literature (storytelling) in the teaching and learning of mathematics is supported by a growing body of research (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).

It has been claimed that 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). 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, fluency building (skill building) and problem solving.

Explicit teaching involves directing students' attention toward particular learning objective through a sequence of supports, involving: setting a purpose for learning (telling students what they are going to learn), which should be based on the teacher's understanding of what students already know; telling students what to

do, then showing them how to do it. This is followed by providing guidance on children's hands-on application of the new learning (Boyles, 2001).

'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). 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.

'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) identifies 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 (HOT), which depends to a large extent on the fluency of lower level learning.

In the teaching of mathematics, research studies have shown that multiple representations (presenting and demonstrating information in more than one medium to support specific kinds of learning) 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; 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; Mishra & Sharma, 2005). 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, Takači, & Milajić, 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) to teaching mathematics as a basis for designing new interactive multimedia software for the teaching and learning of mathematics in the lower primary classroom.

Instructional system design: the ADDIE framework

Instructional system design is described as “[T]he systematic development of instructional specifications using learning and instructional theory to ensure the quality of instruction” (Moallem, 2001, p. 113). It includes the entire process of: the analysis of teaching and learning needs and learning objectives; and the development of an instructional system that meets those needs. 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 teaching and learning tools. Different activities in the various phases of the ADDIE model is summarised in figure 1.

Theoretical Framework: the composition of educational framework and instructional system design components

One of the main aims of the study was to design and develop a dynamic computer-based multimedia application to facilitate the teaching and learning of mathematics concepts in primary classrooms. To create such a dynamic system, (a) a systematic system design process, and (b) an educational framework, were required. They were then applied in order to target the specified educational objectives. The ADDIE framework, explained above, was used as a systematic instructional design model which provides a step-by-step procedural blueprint for: the analysis of the teachers’ and learners’ needs; the definition of the goal/s of instruction; the design and development of multimedia materials and tools to assist in the transition; and the evaluation of the effectiveness of the educational intervention.

The study being reported here draws on a cognitivist approach to learning, which focuses on mental

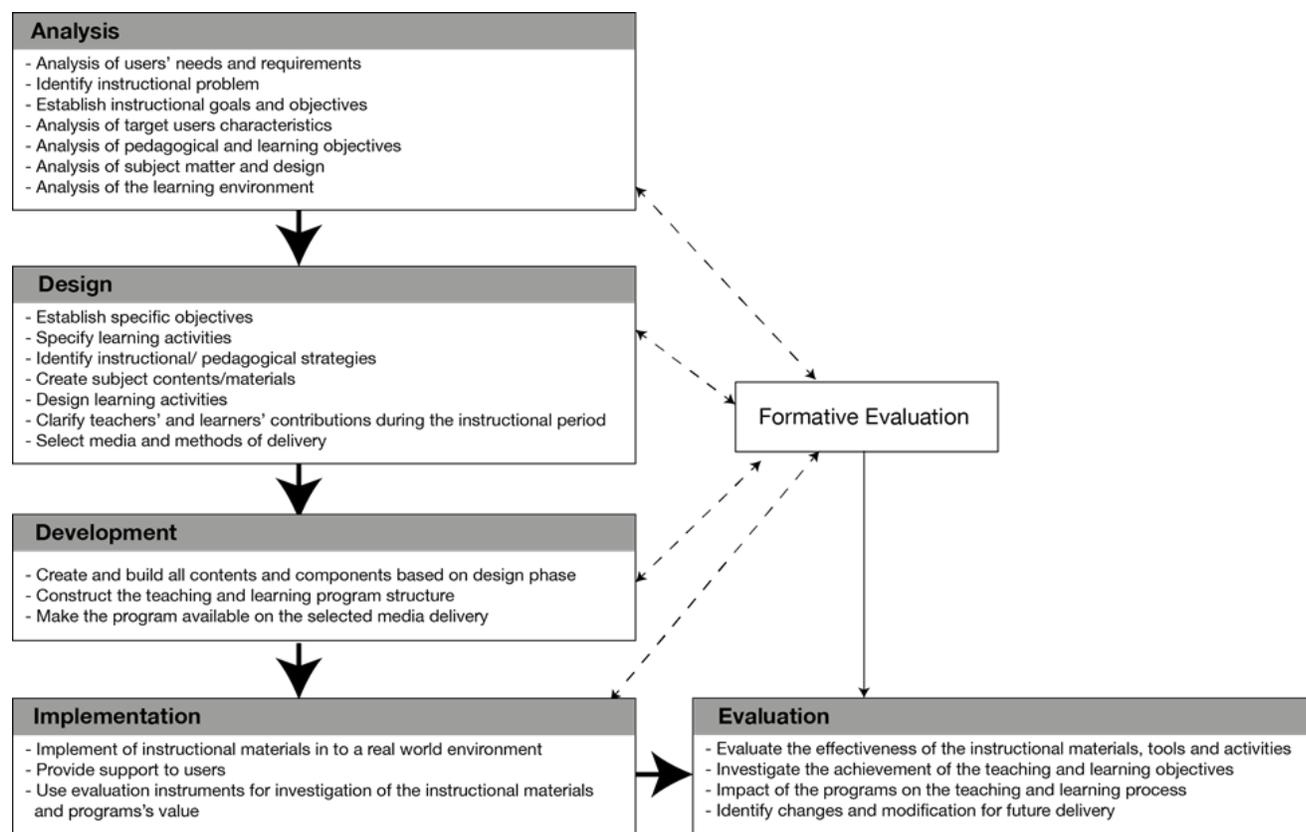


Figure 1. Summary of activities in the various phases of the ADDIE model of instructional system design

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). The Bloom/Anderson taxonomy is a hierarchical model for cognitive learning objectives, ranging from lower levels of learning (i.e. knowing and understanding) to higher levels of thinking, which involve of the synthesis, evaluation and analysis of content. The taxonomy consists of six major categories including Remembering, Understanding, Applying, Analysing, Evaluating, and Creating (Anderson, et al., 2001). The first three categories 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 analysis, evaluation and creativity.

This study proposes a new educational framework for designing mathematics multimedia software, which captures all elements of the Bloom/Anderson taxonomy (Figure 2).

The educational framework of cognitive learning objectives, which draws from the Bloom/Anderson taxonomy, also influenced the instructional design process of this project. Various educational objectives and techniques based on cognitive learning theory, such as breaking information into small parts, memorising content and practising, storing and retrieving information, were applied to the instructional design process. Figure 3 illustrates the composition of the instructional design

components, which incorporates cognitive learning theory based on the Bloom Anderson taxonomy, to shape and define computer-based instructional materials for assisting in teaching and learning mathematics in lower primary school.

ADDIE comes to life: using the instructional system design principles to My Maths Story project

The study aimed to design and develop computer-based multimedia application (software) based on a strong educational framework. With the underpinning educational framework, along with the capability of multimedia technology for presenting multiple representations, as well as the use of children's literature for teaching mathematics, it was possible to design and develop two sets of interactive multimedia educational software named My Maths Story Tools 1 and Tools 2. The two sets of multimedia applications were designed and developed following the guidelines of the ADDIE instructional design model as a systematic approach to analysing the specific teaching and learning needs and the development of tools to meet the needs. The next section of this article discusses the design and implementation process of Tools 1, based on the ADDIE model, taking into account the educational framework components and trialling the developed tools in real world settings.

Analysis

As mentioned earlier, disconnections between theory for designing educational applications and theory concerned with applying

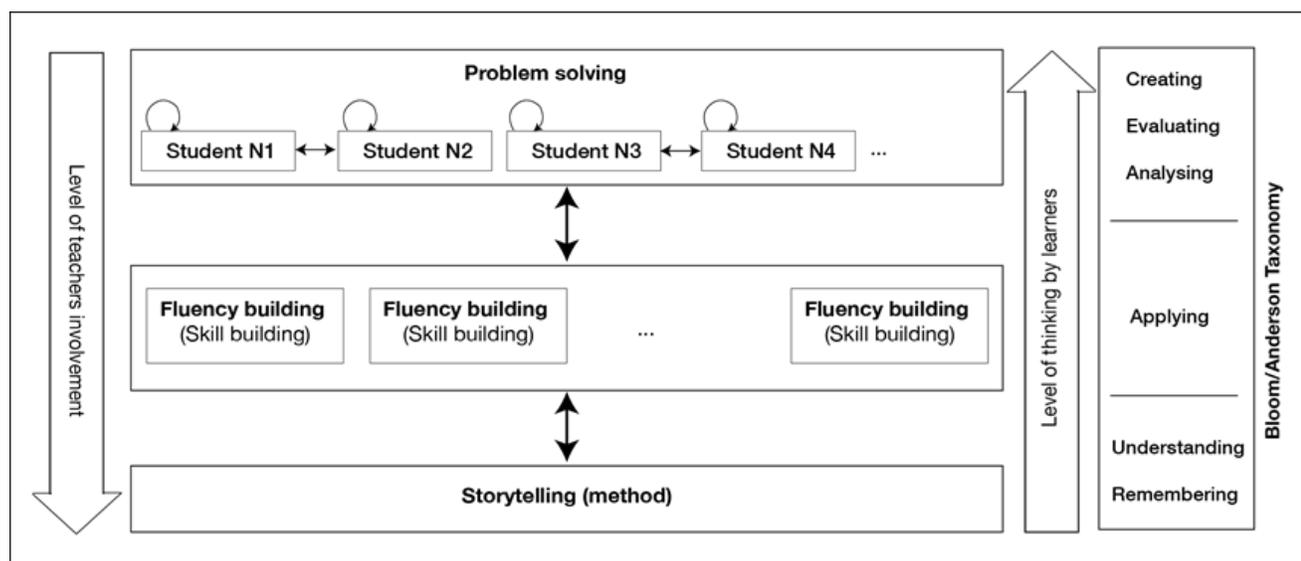


Figure 2. The proposed educational framework of the cognitive learning objective

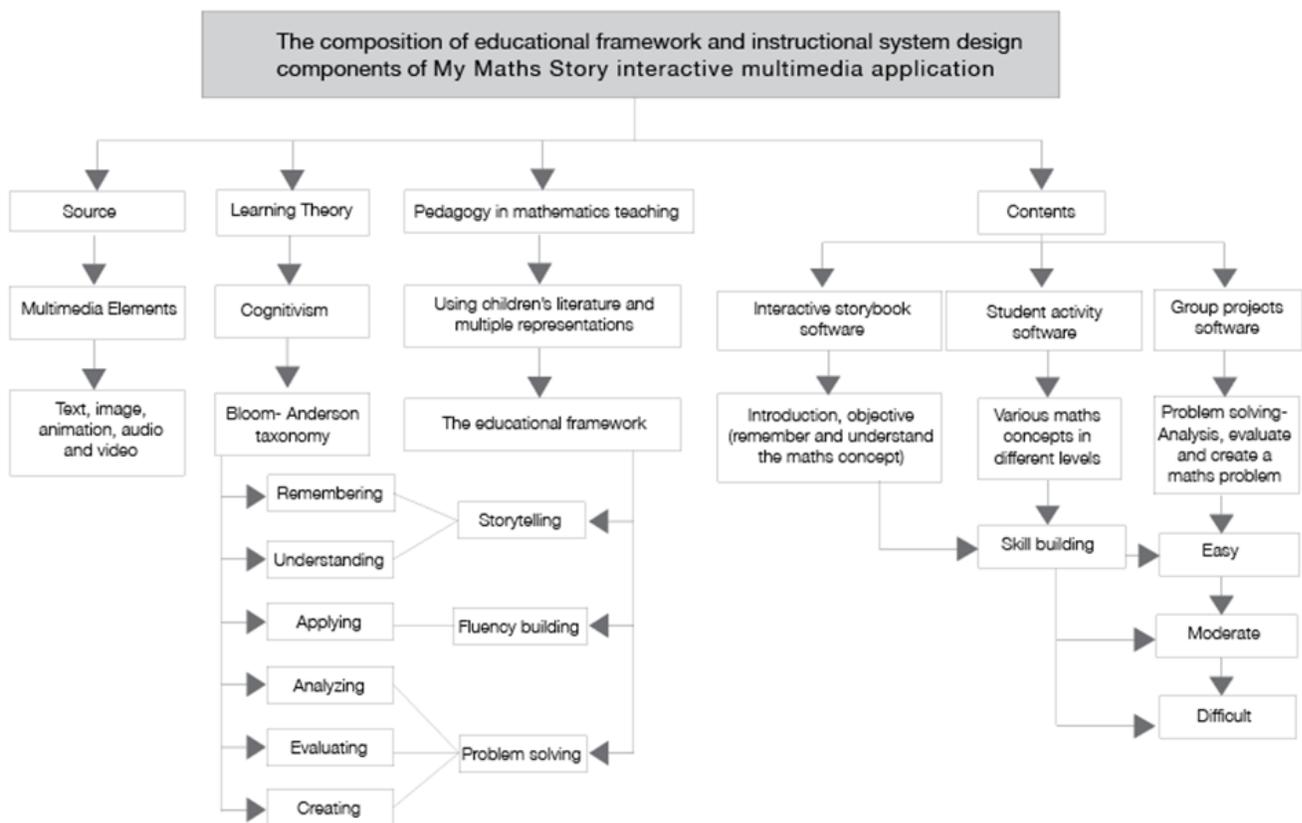


Figure 3. The composition of the educational framework and instructional system design components

educational application for teaching in classrooms, coupled with a lack of alignment with curriculum and instruction to support learning, have been highlighted as main issues that can hamper the quality and relevance of existing computer-based educational applications. To overcome this problem, detailed analysis of the following areas took place within the analysis phase of the ADDIE model: (a) users' needs and requirements; (b) target users' characteristics; (c) pedagogical and learning objectives; and (d) subject matter and design, along with the establishment of instructional goals and objectives.

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:

- Interviews and discussions with teachers and mathematics educators about designing a new software based on mathematics classrooms' needs;
- Review of literature and direct observation in classrooms to ascertain limitations of existing mathematics software
- Observation of mathematics activities (computer-

assisted and non-computer-assisted) in classrooms;

- Identification and examination of some of the preferred computer-based educational applications used in Australian primary school classrooms
- Study of mathematics pedagogies in early childhood and lower primary;
- A review of the Australian Curriculum- mathematics;

These activities helped the main 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.

Analysis of target users' characteristics: Junior primary school teachers and children (K to Year 4) were the main target users of this study's multimedia software. Teachers' experiences in using computer based applications and their beliefs and acceptance of using new technologies as teaching tools were varied. A range of technology skills among participating teachers, as main target users of the new multimedia software, was noticed through an analysis of teachers' characteristics. Learners (primary school children), as the second main

target users, were not a homogenous group either. However, a great deal of knowledge of technology skill was not expected from children of such a young age. Almost all children in this age group could click, drag and drop an object by mouse or on a touch screen. It was found that children attitude and acceptance of using technology was generally positive. The target users' characteristic analysis informed the design and development process of the new application to ensure that the final tools meet the needs of all target users.

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; Gagne, Wager, Golas, Keller, & Russell, 2005). Pedagogical objectives can be described as what students will be capable of doing after the lesson or sequence of lessons (LeLoup & Ponterio, 2003). Goals and objectives need to be specific and align with the curriculum with a clear outcome. 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 the study was to design and develop a multimedia application that teachers could integrate in their classroom to teach the Number and place value sub-strand of the Australian curriculum.

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 directed by the pedagogical and learning goals. Part of subject matter analysis involves searching for optimal resources. As mentioned earlier, using children's literature is an effective approach in mathematics education for young children and was acknowledged (by participating teachers and mathematics educators) as an appropriate and accepted teaching method in Australian mathematics classrooms. 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 the My Maths Story -Tools 1.

Design

The data from the analysis phase provided important information to support decisions in the design stage. This information was used to assist in the identification of areas where multimedia might add value in mathematics teaching and learning.

The proposed educational framework, which captures all elements of the Bloom/Anderson taxonomy, was used as a guide in selecting and designing instructional strategies to address the teaching and learning goals and objectives. 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, Fluency Building (Skill Building) and Problem Solving and Peer Partner Learning. The multimedia educational tools contained three components, which applied all elements of selected instructional strategies at different levels of the conceptual framework, including: (1) Interactive Storybook software; (2) Students Activity software; and (3) Group Project software.

Interactive Storybook software: Storytelling or using children's literature is the first level of the educational framework (lower section), where the whole class can be engaged. However, teacher involvement (scaffolding) to focus children's attention on the story and the embedded mathematical concepts and the building of comprehension is substantial at this level. Through storytelling and the use of elements of the chosen mathematics concept storybook (e.g. characters, scenes, numbers, words), the areas where multimedia (e.g. image, text, sound, audio, animation) might add value in the mathematics teaching and learning in an engaging ways were identified.

The first component of this study's educational tools, *Interactive Storybook software*, was based on the instruction strategies in the described sequence through, explicit teacher modelling and scaffolding instruction. As noted above, 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 snails have one foot, while a person with two feet represents number "2", and number "3" is represented by a person (with two feet) plus a snail (with one foot). The same theme was carried out in the software by presenting and focusing on a particular numbers 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 ability to interact, modify and create a new story. Various media elements were identified to symbolise the particular number (multiple representations) in each screen, along with

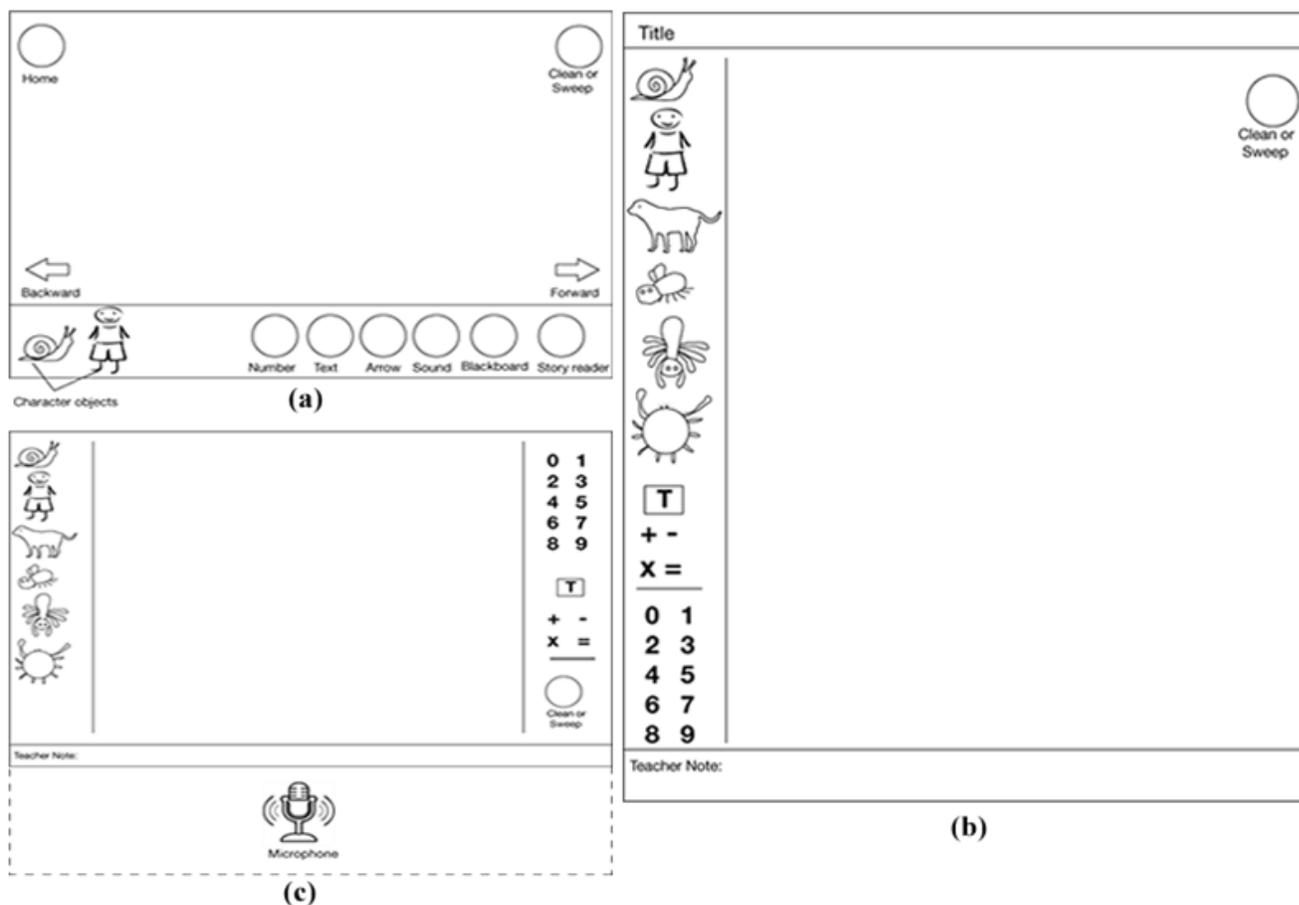


Figure 4. Sample illustration of (a) the Interactive Storybook software design strategies (b) the Student Activity software (c) the Student Group Project software

ability for users (teachers and students) to create a new mathematics related story. Figure 4.a illustrates an early stage draft of the Interactive Storybook software’s design strategies.

Teachers can use the Interactive Storybook software to introduce, model, show or discuss many mathematics concepts related to the “Number and Place value” sub-strand of the Australian curriculum. The story can be read to children (by click on the Story reader icon) first, then teachers can introduce a particular number in multiple representations, including; visual, numerical, alphabetical and audio (counting by sound). Teachers 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 of the lesson by answering the teachers’ questions through manipulating, adding and removing objects on the screen.

Student Activity software: The second component of this study’s educational tools, *Student activity software* was based on building the skills of individual students through the use of knowledge and understandings already gained through the first level. This captures the middle level of the educational framework, which was

based on the *Apply* category of the Bloom/ Anderson taxonomy.

The mentioned elements of the story (characters, scenes, numbers, worlds), 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 the skill building (fluency building) through the drill and practice strategy (Figure 4.b). Through the elements of the Interactive Storybook software, teachers can introduce and demonstrate a specific subject then gradually move students to the second component to practise and memorise 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 software by creating different stories about skip counting. After children gain knowledge and understanding of the concept, teachers can use the second component 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 quickly recalling factual knowledge and concepts. Furthermore, students can receive immediate

feedback from teachers on their work and increase their acquisition of specific skills in the specific area.

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

This component contained all of the elements of story and multimedia used in the Interactive Storybook and Student Activity software. However, this component had an extra feature for recording children’s voices while they solved a maths problem individually, in pairs or in small groups. This is a feature to help teachers assess students’ mathematical thinking through verbalisation (thinking aloud) while solving a problem. Teachers can divide their students into pairs or small groups and pose a maths problem (e.g. mathematical word problem), with story elements providing motivation and context, 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 access this for analysis. The listening ability of children (verbal) and seeing the final solution to the maths problem on their workstation (computer screen) or printed paper (non verbal) will also provide important assessment information for teachers, including: children’s thinking and understanding by drawing on their previous knowledge, their ability to apply this knowledge to assist in finding a solution to the problem. Teachers can also identify children’s misconceptions and confusions relating to particular concepts through this process (Figure 4.c).

In the final stage of the design phase, a formative evaluation was conducted to gain feedback on selected instructional strategies, multimedia elements and subject matter. The designed components were presented to three lower primary school teachers and mathematics educators. Different pedagogical strategies, 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 before the decision was made to move onto the development phase.

Development

The development phase was based on the results of the analysis and design phase. Detailed information from the design phase provided guidelines for the development of the multimedia educational tools. The application, My Maths Story, was designed and developed by one of the researcher in a computer science lab. Through the development process, operational functionality, graphical elements, software interface, media pro-

duction and testing 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 phase, were created in this stage (development phase).

Formative evaluation: A substantial formative evaluation was conducted after executing the development phase and before implementation of the multimedia software in schools. For this purpose, the developed tools were presented to 32 pre-service teachers and 2 early primary mathematics educators at a university in Western Australia. Each pre-service teacher and mathematics educator assessed the application for approximately 25 minutes. Through this evaluation process, several technical issues were detected, for example the “Sweep” (Clear) button did not remove all objects in some pages. Pre-service teachers suggested modifications to some of the software elements such as: “*It would be good to have a “replay” button for each numeric and alphabetic animation.*” The survey and interview data were analysed and necessary changes were introduced to improve the tools. Once this process was finalised, the tools were considered ready to move to the Implementation phase.

Implementation

In order to demonstrate the value 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 teaching and learning different mathematical concepts. The software applications were used in classrooms (on interactive whiteboards) for whole class engagement 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 for younger children, 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 throughout the terms. Teachers created various interactive stories by choosing scenes, characters (e.g. a snail, person, dog, insect, spider, crab) and appropriate multimedia such as sound and text (figure 5.a) and emphasised 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



Figure 5. (a) Teachers using the tools in mathematics classrooms, (b) Students using the tools independently, (c) Some examples activities created in the Student Activity software, (d) Student using the tools in pair or small group

remembering, describing and explaining (the "Remember" and "Understand" categories of the Bloom/Anderson model-lower level of the educational framework).

Through interacting, manipulating, and creating various stories, students 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 educational framework) (figure 5.b). Teachers also used the Student Activity software to create various mathematics activities for their class students in different formats (print and interactive) (figure 5.c). The software was also used for teaching more complex concepts through teachers generating a story or a mathematics word problem and then asking students to analyse, explain and solve a problem individually or in pairs (the "Analyse", "Evaluate" and "Create" categories of the Bloom/Anderson model – upper level of the educational framework) (figure 5.d).

The researcher was consistently available and accessible to participant teachers to address technical and pedagogical issues and questions during the implementation stage. Towards end of the school term, individual and semi-structured interviews with the participant teachers occurred. Furthermore, teachers were asked to complete a questionnaire.

Evaluation and Findings

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

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 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.

"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 permitted through being able to change and modify 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.

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 or in pairs, were highlighted as advantages of the application by all participant teachers.

"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 big difference between these two types 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, or work as pair on a problem." Year 3 teacher.

However, teachers requested some new features for the development of future application such as the ability to move the text box around the screen or remove it from screen by dragging to "Sweep" button or the ability to change some of the story elements' size (enlarging and minimising).

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 multi-modal way, and having the 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 memorise basic addition facts, for example, 6 and 4 always make 10... that was 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 help them to memorise the fact 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 sign... I am going to use the software for explaining and modelling subtraction and take away concept next week." Year 2 teacher.

Using children's literature to explain the abstract concepts of mathematics also specified as an advantage of using the application in teaching and learning process.

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

Many teachers reported that their students showed increased comfort levels in talking about their understanding of mathematics concepts through making their own story and sharing and discussing it in the classroom. Memorising and practising a mathematics fact and helping children build skills through motivational tasks, using the story's characters, were mentioned as benefits of using the tools.

"I found, it [the software] helped my children to memorise number facts.... It was fascinating for me to see... (student name), working on basic number fact 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 group of eight that make 16. It was fascinating to see her doing and reasoning like that when, 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 strengths 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 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 into to the class, first they asked, “What is this?” and then they said, “Can we do it?” I let them to 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 unanimous 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 multimedia software instead or alongside traditional books in their classroom. However, teachers suggested variations to the software, including the use of more mathematics language vocabulary and terminology, an increased number of characters, elements and story plots and the provision of hands on (concrete, non-digital) material based on the story’s character and themes.

Discussion and summary

The findings indicate that teachers were able to define and set certain mathematics pedagogical and learning objectives that aligned with the Australian Curriculum and use the multimedia application as a teaching tool to teach the planned objectives. 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 engaging and faster and deeper way than in traditional way. Also, the findings reveal that the software helped to activate students’ curiosity about mathematics topics, to engage them in the learning process, to interact with content, to keep them on task, to provoke sustained and useful classroom interaction and, in general, to enable and enhance their learning of the subject content individually and in pairs or small groups.

The ADDIE instructional design model was found to be a useful guideline for building effective teaching and learning tools. The formative evaluations during the various phases of the model informed the researcher to determine whether teachers and students would use the software product to reach their teaching and learning

objectives, and how it could be improved before implementation in real world settings.

Conclusion

This paper has proposed that a lack of alignment between technology, curriculum and pedagogy in many existing mathematics computer-based applications is one of the main reasons underlying teachers’ rejection of mathematics software in Australian primary school classrooms. To address this problem, a theoretical framework, based on accepted pedagogical strategies by Australian primary teachers and educators, was used as a basis for the design of new software. The ADDIE instructional system design was used as guide the process of designing, implementing and evaluating the software. This paper has also described this process, as well as the findings of the My Maths Story - Tools 1 project. The findings indicate that the application, because of the strong theoretical and pedagogical underpinnings, did not share the limitations of many existing computer-based mathematics applications. The application appears to hold considerable potential for teaching mathematics in junior primary mathematics classrooms through storytelling and the use of multimedia technology to present multiple representations. However, teachers requested some new features, which directed this study to development of the second tools (My Maths Story-Tools 2), which will be discussed in a future paper.

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For more details of the educational theoretical framework please see another publication by authors:
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