

Going on Safari: The Design and Development of an Early Years Literacy iPad Application to Support Letter-Sound Learning

Sophie McKenzie¹, Aaron Spence¹ and Maria Nicholas²

¹Deakin University, School of Information Technology, Geelong Waurin Ponds, Australia

²Deakin University, School of Education, Geelong Waurin Ponds, Australia

sophie.mckenzie@deakin.edu.au

Abstract: This paper explores the design, development and evaluation of an early childhood literacy iPad application, focusing on the English Alphabet, called 'A to Z Safari' trialled in Australian classrooms. A to Z Safari was designed to assist students in the early years of schooling with learning the alphabet and building on their knowledge of letter-sounds. This paper details the process that led to the design and development of A to Z Safari and evaluates the success of the application (also known as 'app'), using the Technology Acceptance Model (TAM), from a classroom trial in 2015. Quantitative data from the app statistics gathered on student use, and qualitative interviews with classroom teachers explores how students and teachers received A to Z Safari. It was found that the design of A to Z Safari exhibited ease of use and usefulness for the target cohort in regards to gameplay and teacher support, however a number of updates need to be made to the app's functionality to satisfy future, larger scale use. Suggestions for those designing similar apps for use in classroom environments have been provided.

Keywords: Games, literacy, digital application, design, phonics, iPad

1. Introduction

Digital devices are common both in-class and out-of-class time across Australian elementary schools with many young learners preferring the digital format (Lynch and Redpath, 2012, Stern, 2014, Flewitt et al., 2014). When implemented effectively, digital devices can provide a highly stimulating, motivational and engaging environment for students, with apps designed to support children's literacy demonstrating positive outcomes (Reid and Ostashevski, 2011, Flewitt et al., 2014). Developing and promoting digital literacies in the early years of schooling has continued to gather interest as smart phones and tablets become pervasive in both the home and school. When considering an early-years multimodal app, designed to support the learning of letter-sound associations, a review of the Apple AppStore showed a number of relevant apps; in particular Oz Phonics (DSP Learning Pty Ltd, 2012) and Montessori (Edoki Academy, 2014). With such a plethora of apps to choose from, it is more than availability alone that will determine whether a particular app will be selected and used by teachers and parents. Two important factors that determine the selection of an app for use in classrooms are whether the app will be effective in assisting users to achieve their learning outcomes, while facilitating high levels of engagement at the same time (Furió et al., 2013, Lynch and Redpath, 2012). This critical intersection requires solid foundations in educational theory and game design to offer an experience that can satisfy the need of both students and teachers. In an effort to push the boundaries of early childhood literacy educational techniques, we developed the app A to Z Safari to provide an educationally sound, game based learning experience for 5 to 7 year old children to learn the English alphabet. The aim of our research was to evaluate both the learning and usability outcomes of A to Z Safari from a small trial intervention conducted within an Australian elementary school. In addition, this research explores the design and development of A to Z Safari to demonstrate how usability was considered at every stage. Further research that presents the learning outcomes from students' use of A to Z Safari can be found in Nicholas et al. (2017).

2. Computer based literacy applications for early years of schooling

Digital devices allow users to engage with and create texts using more than one mode of communication, whether it be through sound, visuals, movement and/or layout. According to Kress and Leeuwen (2001), users of multimodal texts are facilitated to engage in meaning making via the four domains through which the text is created (Figure 1).

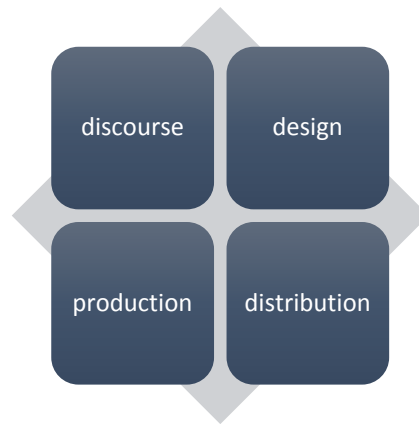


Figure 1: Kress and Van Leeuwen's (2001) four domains - the multimodal text

Though all four domains are interrelated and critical, the 'discourse' domain is the quadrant that most directly influences the design, production and distribution/promotion of a multimodal app that seeks to support users to acquire new knowledge. Kress and Leeuwen (2001) define discourse as "socially constructed knowledge of (some aspect of) reality". Supporters of socio-constructivist theories postulate that knowledge is socially constructed through interactions with others, which in turn have been influenced by an accumulation of social actions over time (Dewey, 1938). Interacting with the multimodal texts found within an educational app created by a team of 'others', is an avenue through which users can engage in the social construction of knowledge.

When creating a multimodal text such as an educational phonics app, Kress and Leeuwen's (2001) description of the discourse domain suggests that it is critical that the most accepted and/or sound discourse be associated with the presentation of letter-sounds (Kress and Leeuwen, 2001). The educational discourse that informed the design of A to Z Safari was drawn from two disciplines: research into the development of reading skills, and that of memory retention. The importance of learning letter-sound associations in the early stages of a child's reading development informed our choice to focus on letter-sound associations for our app's design (Australian Government, 2005, Burgess and Lonigan, 1998, Melby-Lervåg et al., 2012, National Early Literacy Panel, 2008, National Reading Panel, 2000, Rieben and Perfetti, 2013, Perfetti et al., 1987, Pfoet et al., 2013, Stanovich, 1986). Dual coding theory (Kuo and Hooper, 2004, Sadoski and Paivio, 2013, Paivio and Csapo, 1973) informed our choice to use both illustrations and language to facilitate the learning of letter-sound associations when designing our app. Dual coding theory shows that memory retention is more effective when a learner uses different types of information concurrently, to facilitate recall. This theory contends that target content is more readily stored in memory and retrievable when images and language are used together, rather than relying on one source of information to aid recall on its own

Our focus on dual coding theory was further enhanced by research that has found that images are more effective in aiding the recall of letter-sound associations when the connection between the image and target memory is more concrete. For example when the letter 's' is superimposed over an illustration of a snake that was crafted to take on the shape of the letter 's', this highlights that the initial sound in the word 'snake' makes the sound associated with the letter symbol 's' (Agramonte and Belfiore, 2002, de Graaff et al., 2007, de Graaff et al., 2009, Diloranzo et al., 2011, Ehri et al., 1984, Fulk et al., 1997, Hoogeveen et al., 1989, Manalo et al., 2013, Sener and Belfiore, 2005, Shmidman and Ehri, 2010). This was further supported by research into memory 'interference', a theory that contends that other memories can interrupt the successful retrieval of sought after memories (Kline, 1921, Danker et al., 2011, Van Dyke and Johns, 2012, Rutledge-Taylor et al., 2014). To minimise interference, more concrete, chain-type mnemonics are needed to lead the learner to the sought after memory (Bellezza, 1981, Levin, 1993). This was illustrated above, where the shape of the snake was crafted to take on the form of the letter 's', so that the learner is not led to associate a snake with the letter 'l' for example, given that a snake can resemble the letter 'l' when laid out straight. Such communion of image and language would ensure that an app designed to facilitate learning based on the conclusions above will have positive outcomes for its users. The combination of image and language has been illustrated in Nicholas et al. (2017) which tested literacy theories used in A to Z Safari's design.

In addition to the educational theories outlined above and detailed in Nicholas et al. (2017) the functional design of A to Z Safari also required careful consideration of design characteristics (affordances) so as to appeal to the target audience.

3. Design affordances and development considerations of digital applications for early school years

Modern tablets and smartphones are becoming increasingly powerful in terms of their processing, memory, and storage capabilities, allowing for sophisticated delivery of a range of digital content (e.g. games, news, and social media). When students use a tablet, they interact with the device through a series of taps, swipes, and pinch-zooms. A review of relevant literature informed the ways in which an app can be best integrated into the classroom environment, as well as providing an effective platform for delivery of the learning material. It has been recommended that the following be considered when designing an app for the early school years:

1. **Interface interaction-based recommendations:** Minimization of interface distractors or creation of what Stern (2014) argued as 'an interface economy'. When constructing a system of feedback that supports different interaction needs, an app needs clear, immediate and rewarding feedback in both visual, aural and oral forms for young learners (Flewitt et al., 2014, Reid and Ostashewski, 2011). Continued motivation should allow students to 'undo' or 'retry' attempts (Flewitt et al., 2014). Furthermore, removal of social media content and complicated controls allows the app and the learner to focus on the primary content.
2. **Subject/Content-based recommendations:** Apps used for learning should include visual and interactive elements that are enjoyed by students. To facilitate an engaging and interactive learning experience, video, images and sound elements should be provided, relevant to the target audience (Stern, 2014). Furthermore, Stern (2014) argued that an app should provide a clear integration of resources that assist learning (for example a glossary). In the classroom, devices should not be considered as personal, but rather reflective of use in the classroom situation. Reid and Ostashewski (2011) echo this on a larger scale acknowledging that digital device use in the classroom can result in many management issues. Central to digital device use, however in particular with younger target audiences is the provision of a safe and secure environment particularly in regards to Internet use and access (Mifsud, 2002, Henderson and Yeow, 2012, Livingstone and Smith, 2014).
3. **Understanding/Learning-based recommendations:** Flewitt (2014) asserted that an app has the potential to support independent learning, concentration, enriched communication and creative collaboration. The evaluation of early-school language apps as completed by the Department of Education and Training (2016) demonstrates a number of ways in which kindergarten and early school age children can have their learning supported while using apps. Learning recommendations include the provision of aural, visual and oral media assets to support varying learning methods as well as personalized learning pathways that offers individualized support of student activities. They also recommend that apps should also support students to develop a variety of foundational skills.
4. **Language/Literacy-based recommendations:** In addition to the above, the Department of Education and Training (2016) outlined a number of ways in which kindergarten and early school children can have their literacy needs supported while using apps. Literacy recommendations include the use of play based learning to support early language learning and using repetition for students to develop their literacy skills through oral and aural means.

Across all recommendations, multimedia is promoted as a key component through which to deliver content via apps, providing a detailed audio and visually interactive experience for users. However, consideration must be given to the type of multimedia being presented, what mode/s will be used (e.g. audio, visual), and how the various modes are combined to convey content. The targeted hardware (Apple iPad) presents constraints for presentation of multimedia (Furió et al., 2013), which need to be considered during design.

In addition to the above recommendations, factors such as usefulness and ease of use should also be taken into consideration when designing technology interventions for the classroom. The Technology Acceptance Model (TAM) considers mediating factors of usefulness and ease of use in relation to system characteristics and the probability of system use. Usefulness is defined as the degree to which a person believes that using a particular system would be useful to enhance his or her job performance (Davis et al., 1989). Ease of use is defined as the degree to which a person believes that using a particular system would be easy to use and/or

free of effort (Davis et al., 1989). The above design recommendations and TAM evaluation metrics were considered during development of A to Z Safari.

4. Design of early childhood literacy application A to Z Safari

A to Z Safari was designed and developed in 2014 to support young children to learn the 26 most common letter-sound associations of the English alphabet. The app also provides teachers with a tool that can support the review and assessment of student learning. A small team comprising of two programmers, a games designer, two graphic artists and two educational consultants worked within an informed research and development framework to ensure a quality and rigorous implementation. The development of a theoretical framework based upon research into children's early reading development and research into factors that aid or hinder the recall of target memories informed app design (Nicholas et al., 2017). In addition, age of intended audience (i.e. 5 to 7 years olds) and intended context (independent classroom use) was considered during the app's design (Reid and Ostashewski, 2011, Watlington, 2011), which included design considerations that would be suitable for display and use on a small screen (Stern, 2014). In addition to the research and development framework, numerous considerations were also taken into account in regards to the hardware requirements needed to deliver the app via our target device, Apple iPads.

A to Z Safari was designed to guide students through self-directed tasks that would support the learning of letter-sound associations. In the design of A to Z Safari, the intention was to create an app that could be used independently by young children in the classroom so that teachers might be free to devote their time to tasks that encourage students to engage in higher order thinking processes. The decision to create an app was informed by the potential that software programs can support independent, self-paced learning of content knowledge that is closed in nature i.e. answers can only be correct or incorrect (Jones, 2009, Kirriemuir and McFarlane, 2006, Busch et al., 2015, Marchetti and Valente, 2015).

In the design of A to Z Safari, images were created in the shape (form-taking) of the letter that they were to be associated with (e.g. a flamingo in the shape of the letter 'f', see Figure 2), so that a more concrete link could be forged between corresponding illustrations, letter-sounds and letter symbols, reflective of research into dual coding theory (see section 2). The form-taking designs shown in Figure 2 intentionally deviated from more traditional alphabet picture cues (e.g. using an image of a flamingo in a more natural pose as a reminder that the first sound in the word 'flamingo' is to be associated with the letter symbol 'f'), which is commonly used in classrooms to assist students to learn and recall letter-sound associations. Our form-taking design was chosen to reflect the theory that creating more concrete links between images and letters, by presenting illustrations (e.g. of animals) in a form-taking shape, can better assist students to remember the associated letter symbol over traditional alphabet picture cues. Figure 2 shows the alphabet chart used in A to Z Safari (Nicholas et al., 2017).

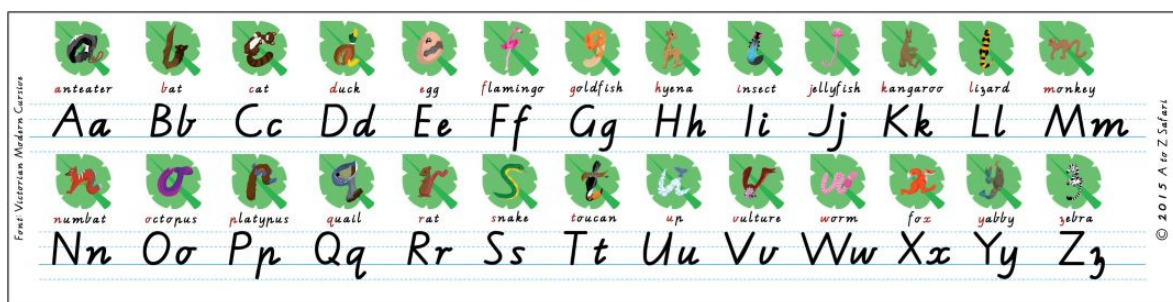


Figure 2: Alphabet Chart of A to Z Safari

The Apple iPad (generation 2 or higher) was chosen to house the A to Z Safari app due to its widespread use in Australian primary schools (Etherington, 2013, Apple Press Info, 2013). The widespread use implies that our intended audience, primary school aged children, would be already familiar with Apple iPads, an important consideration to the adoption of a new technology in the classroom (Lynch and Redpath, 2012). The development environment for the iPad is also well supported with a mature, well-established development toolset along with easy access to well-established communities of support. During development and subsequent testing of A to Z Safari, the development team used Xcode 5, targeting iOS 8, the iPad 2, and the iPad Mini 2.

To facilitate interaction with the form-taking illustrations designed for A to Z Safari (Figure 2), the app offered users two categories of games: match (Figure 3) and memory (Figure 4). Within each category, users could select from five levels that allowed them to interact with the letter 'leaf' tiles (Figure 2) in different ways. Table 1 describes each level, available within both game categories, in A to Z Safari. Within each level, users were presented with activities that were associated with all 26 letters that queried their competency.

Table 1: Description of A to Z Safari Game Levels

Level	Match and memory game description
Level 1	Users are presented with spoken words (for example 'cat'), required to partner with letter tiles.
Level 2	Users are presented with spoken letter-sounds (for example /s/), required to partner with letter tiles.
Level 3	Users are presented with written letters, required to partner with letter tiles (Figure 3)
Level 4	Users are presented with spoken letter-sounds (for example /s/), required to partner with letter symbols written in plain font (not letter tiles)
Level 5	Users are presented written letters, in a different font than previously used, required to partner with letters written in plain font (not letter tiles)

A to Z Safari also consisted of a welcome screen (Figure 5) and a teacher/administration area (Figures 6 and 7) where the classroom teacher can setup a class list and begin or end 'assessment sessions' to enabled the gathering of user statistics (see section 4.1). The assessment sessions support the match games.



Figure 3: Example of a Match game in A to Z Safari



Figure 4: Example of a Memory game in A to Z Safari

When approaching the design of A to Z Safari it was important to build a visually appealing, flexible, yet easy to use app framework based on interaction, content, learning and literacy recommendations. In A to Z Safari, 'interface economy' (Stern, 2014) was established via a combination of audio and visual elements that prompt the user to explore the games. To ensure a clear introduction to the content the landing screen was purposefully designed with bright colours and large buttons to allow players to engage with the games. With each interaction, A to Z Safari rewards users with positive audio feedback and details their progress via appropriate visual feedback. Influenced by Flewitt et al. (2014), A to Z Safari encouraged players to 'try again' if they cannot provide the correct answer, minimising negative feedback to maintain player motivation.

4.1 Data analytics

A to Z Safari allowed classroom teachers to enter the name, age, and gender of each student within their classroom, stored behind a password protected 'teacher' area. User statistics were stored in one device (normally the teacher's) and not shared across other devices. A database was required to store these user statistics, with SQLite 3 chosen due to being lightweight, and able to run natively within any iOS app as it is included within the iOS API. As advised by Stern (2014) and Reid and Ostahewski (2001), to provide a high level of security and to constrain data management issues, only the teacher area had the ability to email user statistics to an outside source. Once the teacher had logged a student's details in the app the teacher could give the device to the child in this 'assessment' mode to play the match game. While in assessment mode, students could complete up to five levels of the match game to test their letter-sound competency. During each level A to Z Safari tracks students' progress on: number of questions played, letters assessed, number of incorrect answers, number of correct answers, which letters were selected in error, and more.

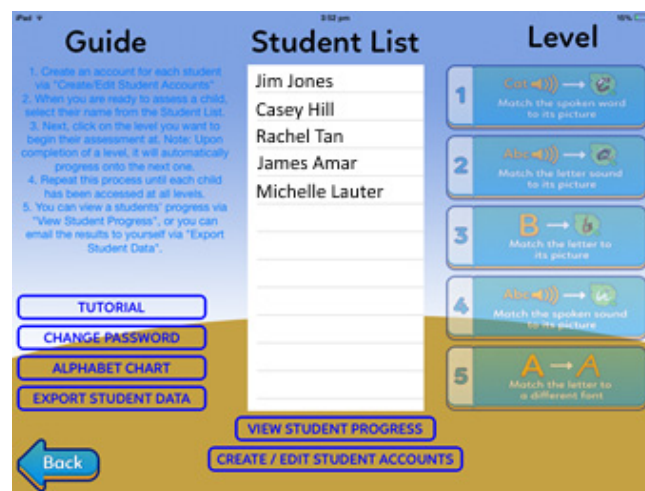


Figure 6: Example of the teacher administration section of A to Z Safari

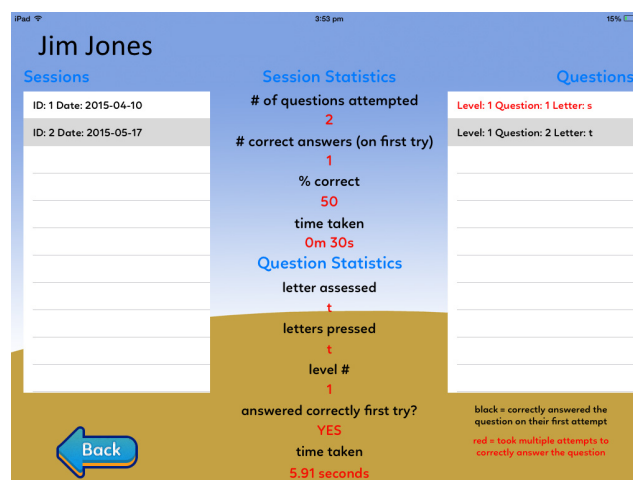


Figure 7: Example of the statistics section of A to Z Safari

The statistics were then available for teachers to measure the effectiveness that the specially designed alphabet lettering may have had on the learning outcomes of the children in their class.

5. Rollout of A to Z Safari

A to Z Safari was used in two Foundation classes (the first year of elementary schooling in Australia) in the second term of a four term year in 2015. The classroom teachers were instructed by the researchers to introduce the app to the children in a small group setting, referred to by the teachers as a 'guided reading' session. Here, small groups of four children were given their own device and guided through the use of the app in the first week of implementation. The teachers ensured that every child in the class (n=32) took part in a guided reading session in the first week of the term. Over the next nine weeks of term the children were directed to engage with A to Z Safari independently of their teacher, in a small group setting for 20 minutes at some stage during their reading sessions. The four iPads in each classroom were rostered to particular groups of children each week, ensuring that each child in each classroom was given time to use the app for 20 minutes once a week for 9 weeks in total. In the 20-minute session each week, each child had access to their own tablet device but were often seen sharing a device and collaborating as they engaged with the games in free play mode (without being logged into assessment mode by a teacher as described in section 4.1). The two teachers who made use of the app were asked before the trial began when they could conceivably see themselves making use of the teacher area and the assessment mode of the app. Both teachers agreed to use it only once towards the end of the term, to inform mid-year student reporting to parents. Data gathered shows that this is indeed when the teacher area was used and user statistics were stored on the devices.

6. Methodology

To evaluate the design and development of A to Z Safari a mixed method was used. As this research is presenting an initial evaluation of the design and development of A to Z Safari, an exploratory mixed method supports the development of further, more rigorous techniques that may contribute to more robust empirical evaluations (Gelo et al., 2008). Quantitative data from 10 consenting students who used A to Z Safari, and qualitative data from semi-structured interviews with two teachers involved in the rollout of A to Z Safari, detail use, as well as exploring ease of use and usefulness of the mobile app. For the results of the usefulness of the app in terms of the learning outcomes achieved, please see (Nicholas et al., 2017). Quantitative data was drawn directly from the user statistics (Figure 7), gathered through use of A to Z Safari. The data shows students' progress when using the app based on: number of questions played, letters assessed, number of incorrect answers, number of correct answers, which letters were selected in error, and more. Each teacher interview was coded using thematic qualitative techniques.

Using the Technology Acceptance Model (TAM) (Davis et al., 1989), we evaluated A to Z Safari in terms of usefulness and ease of use when implemented in the classroom. Usefulness and ease of use are crucial for A to Z Safari to be used by students and teachers in the classroom. This evaluation was informed by data generated from semi-structured interviews with teachers. Questions included: From your perspective did you find the teacher area, as included in the app, easy to use? and Overall was this software useful to your classroom experience? While this research did not complete empirical evaluation using TAM factors, the model is beneficial to guide preliminary evaluation and to support further design and development efforts of A to Z Safari. Ethical approval was sought from relevant institutional ethics committees to interview staff and to utilise consenting students' usage data.

6.1 Research questions

The aim of this research was to present the design and development of A to Z Safari, and evaluate the usability of the app. To achieve this aim, this paper addressed the following research questions:

1. What does the data analytics reveal about student use of A to Z Safari while on trial in an Australia elementary school?
2. What is the perceived usefulness and ease of use of A to Z Safari by teachers involved in a trial in an Australian elementary school?

7. Results and discussion

7.1 Use of A to Z Safari by students

To address the first research question, regarding the data analytics on student use of A to Z Safari, user statistics were analyzed using quantitative techniques. A summary of student data from one game-play session, across five levels within the match game (refer Table 1 for level definitions), is shown in Figures 8 and 9. When engaging in each of the five levels of A to Z Safari, Figure 8 shows the average correct answer percentage for all students ($n = 10$). The correct answers percentage (y-axis) refers to student attempts who correctly selected the correct letter on their first try.

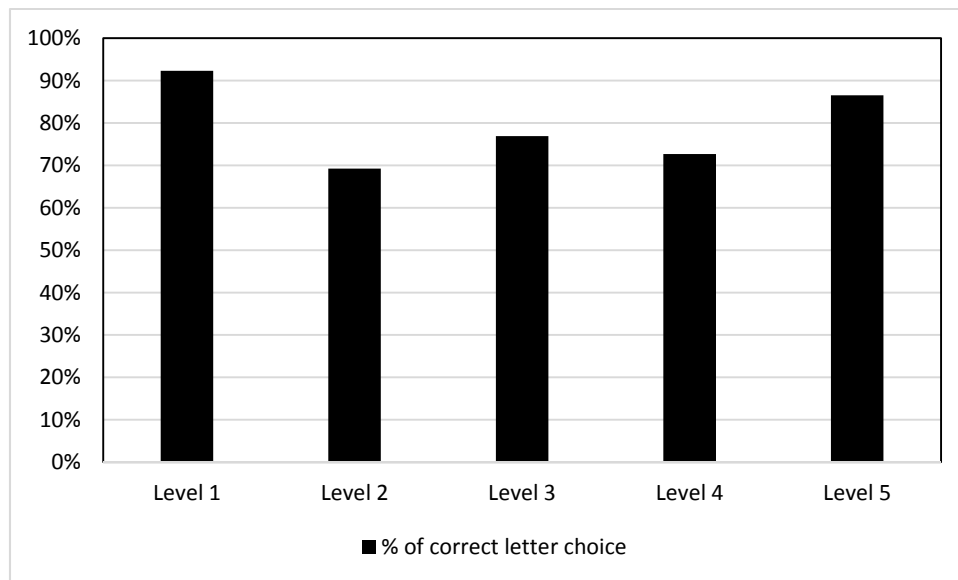


Figure 8: Average correct letter choice made by students

The results in Figure 8 show that across all five levels students achieved above 60% accuracy when identifying the correct letter choice in their first attempt. In addition to the information in Figure 8, further analysis of student data uncovered that the lowest scoring letters across all students ($n = 10$) across the five levels were: K, P, Q, U, V. Figure 9 shows the average time, in seconds, for all students ($n = 10$) when engaging with A to Z Safari across the five levels.

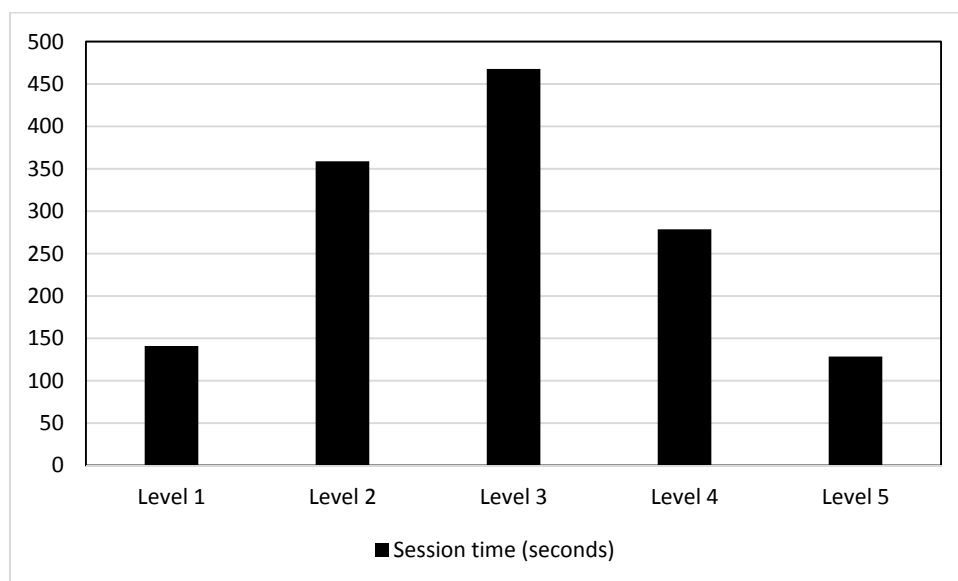


Figure 9: Average session time by students when assessed by A to Z Safari

The results in Figure 9 show that level three (matching images to letters) had the longest session duration on average, with 465 seconds recorded. Time taken for students to complete levels can be an indicator of difficulty in identification of letter-sound association. In addition to the information shown in Figures 8 and 9, data on the number of times students asked for a repeat of the question instructions (or re-ask count) was also recorded by A to Z Safari. The students did not request any repeat instructions in levels three (matching images to letters) and five (working with different font styles). Level four (matching font letters to spoken sounds) demonstrated a high re-ask count with on average 20 re-asks, level two showing on average 14 re-asks (matching pictures to spoken sounds), and level one (matching images to spoken words (the name of the image)) showing three. Time taken to complete a level, when reviewed in light of the 're-ask' count, demonstrates that students would ask for a repeat of question instructions only when the task involved listening (such as identify the letter based upon the sound). When A to Z Safari requires students to listen carefully to projected sounds of letters, this could be an issue in noisy classroom. Our investigation also revealed a lack of opportunity to provide students with the ability to review letter-sound associations outside of gameplay. A to Z Safari provided no resources, such as a dictionary or glossary, as suggested by Stern (2014).

7.2 Teacher evaluation of A to Z Safari

To address research question two, regarding the usefulness and ease of use of A to Z Safari by teachers, teacher interview data was analysed using qualitative thematic analysis techniques. Two teacher interviews were available for analysis. The following describes the themes uncovered during analysis supported by direct quotes from teachers. Two initial themes of ease of use and perceived usefulness seeded qualitative analysis, with further themes identified through a process of iterative dual researcher analysis. In terms of ease of use of A to Z Safari, themes included: ease of use of the games (Figures 4 and 5) and the teacher area (Figures 6 and 7). Usefulness themes included: overall usefulness for letter competency and usefulness of the teacher area.

7.3 Ease of use of the games in A to Z Safari

The games provided students with two ways to interact with the alphabet chart (Figure 2). Both teachers reported that initially they were somewhat confused on how to play each game, commenting specifically on the memory game. One teacher commented:

"Teacher one and I had a chat because we were confused about it at the start... Once we understood it was a memory game we knew what to do, but on first sight we were a little bit confused ... I think it was the randomness that we found a bit confusing." – Teacher Two

This is further reiterated by additional teacher comments:

"It was slow in the early stages as we had to talk to the kids about what those animals were and get them to recognise them." – Teacher One

After an initial period of learning, the teachers reported that both students and staff had increased ease of use in regards to the games and how to play. Importantly, the teachers commented on the fact that instructions on how to play were easily accessible:

"The elephant [see Figure 4] was useful instruction to help guide the kids". – Teacher Two

Clear tutorials are therefore required for both teachers and students to provide ease of use.

7.4 Ease of use of the teacher area

During data collection, it was uncovered that teachers had trouble with successfully exporting students' data from A to Z Safari. While the teachers managed the classroom by allocating one tablet to assess each student, teachers had difficulties understanding how to link A to Z Safari to an email account. Therefore, teachers could only review the information on the iPad, but could not export it as a spreadsheet to be used on their desktop machines. However, despite misunderstanding how to successfully export the data, many positive comments regarding the statistics were captured in the teacher interviews. Teachers commented that set-up of the teacher area was 'straight-forward' and found the data that was captured during assessment easy to follow.

One teacher commented:

"The instructions in the teacher area were useful. You could always go back and check, and you could have a look before giving it to the kids".

One teacher commented on the autonomy the assessment component of the teacher area provided for their classroom:

"I did like how the assessment at the end, didn't require any teacher time. You could just give them the app, as they were used to seeing it, and you could do an independent assessment. A lot of assessments get put off for that reason. The [other] kids are going crazy while you're trying to do it". – Teacher One

It was noted however, that when the teacher section of A to Z Safari was first introduced, the teachers were asked when they could realistically foresee themselves making use of the function. Both teachers declared that they could only see themselves using the independent assessment area once over the 10 weeks of the trial, coinciding with their mandatory report writing. Consideration of Davis et al. (1989) who defines ease of use as the degree to which a person believes that using a particular system would be free of effort, this calls into question the perceived ease of use of the teacher area. Or perhaps it is a question of usefulness rather than ease of use. We were able to rule out the possibility that the data that was generated was difficult to interpret as one of the teachers commented:

"The way the data was presented, once you had tested them, was easy to follow." – Teacher Two

7.5 Overall usefulness of A to Z Safari on letter competency

The teachers used A to Z Safari in many ways in the classroom and found that the app assisted their job performance. One of the teachers suggested that the app added to the everyday teaching and learning practices in the classroom contributing to the success of the teacher's program by providing 'novelty' and a new way of learning that seemed to facilitate motivation and engagement. When asked if use of the app contributed to their students' learning of letter-sound mapping, Teacher One responded with:

"Absolutely, yes. Particularly when you are working with students who are picking up things at home, picking up things from listening, picking up things they do at home and then there is the ones who don't do any of that. Who don't tune in on the floor. I think those are the ones who really benefit from this because it is a novelty, they know how to use it, and it really helped the lower fraction stay on task a little bit more and learn some sounds."

The ability to learn more than one letter-sound combination while using the app was also highlighted:

"It saves a lot of teaching time with letter-sounds, because it is a big thing, you can't teach all 26 [letters] in one hit. You can still take a guided reading group [while other children are using the app]". – Teacher Two

These comments suggest that while there was a 'saving' of planning and preparation time once the children were familiar with its use, it cannot be assumed that this will happen from the outset or quickly with all children. Time needs to be invested when the app is first introduced, with some students perhaps needing more time than others, to fully realise its usefulness otherwise its usefulness may be compromised.

Overall, the teachers commented that A to Z Safari was useful in supporting their classroom programs however some limitations were noted. One teacher commented on the requirement for students to critically think about their answers/input when using the app, rather than allowing the digital device to facilitate forced feedback:

"We did have to have a big talk, and I guess this happens with all apps, in that the kids had to think about the answer and not just guess or look for the correct sound. There was a bit of tutoring at the start." – Teacher One

The need to steer students away from ‘guessing’ when using A to Z Safari, is an important consideration and impacts upon the longer-term usefulness to assist children to learn common letter-sound associations. For example, Teacher One commented that students had issues with certain letters in A to Z Safari:

“...for UP they would go ‘bird’. But as we got through our weeks and our letter-sounds and they were learning more they got better. With /u/ or UP they were expecting an animal or bird, and not an action.” – Teacher One

The ‘up’, /u/ (see Figure 2) connection may have been a design issue rather than one associated with the time taken for students to learn new vocabulary. Given that all image/sound connections were related to animal sounds, this deviation for the letter ‘u’, linking the word ‘up’ to the image used, may have contributed to the difficulties some students had in learning the connection between word, image and letter-sound in this instance. As identified in section 7.1 the letters K, P, Q, U, and V all scored lowest across the five levels of match games. Images such as ‘vulture’ /v/ were observed by teachers to be difficult for students to identify, perhaps due to the students not being very familiar with the animal, which is something to take into account in future designs of the app. Additionally, teachers further commented that students sometimes had difficulty hearing sounds projected from the iPad, which impacted on situations where matching sounds to a picture were required.

7.6 Usefulness of teacher area

Both teachers saw value in the teacher area as a way to keep track of students’ progress with letter-sound competency. Some issues occurred concerning accessing the data (as covered under 7.4 Ease of Use of teacher area), however overall the integration of data analytics was deemed useful to assist the teacher in their job performance:

“The data was useful, I found it very specific as it goes through each round. So I had to think about what was that round, was it knowing the picture, was it knowing the sound? For the stronger kids I found it the most useful.” – Teacher One

Furthermore, teacher comments indicated that they perceived the teacher area would be useful in assisting to write student reports. This suggests that teachers saw this function as summative rather than an ongoing formative assessment that could inform their planning for teaching and learning. Teacher Two commented on data analysis features that would be useful:

“So a summary, per student, to show where they struggle. For example, they struggle with the /q/ sound. At the moment it is based on session, which I had to go through. The session data is useful I wouldn’t get rid of that, but when it comes to report writing time the summary data would be really useful.” – Teacher Two

This was reiterated by Teacher One who also suggested that summaries would have been useful, indicating that she did not make use of the data to inform her daily teaching, using it instead to inform the writing of her mandatory student reports:

“It would be nice if it popped up on the page with a percentage, I have looked at the individuals but it would be good to look at the class.” – Teacher One

These comments highlight possible issues with usefulness of the app to inform changes to daily teaching practice, and provides suggestions on changes that could improve usefulness such as easy to access collated user and cohort statistics. Despite drawbacks with the way in which A to Z Safari presented data to the teachers during the trial, Teacher Two commented that she still found the data that was generated to be useful, commenting:

“For the stronger kids I found it the most useful. What was confusing them? Was it the sound? Were they confusing a letter with another letter?”. – Teacher Two

Overall, the teacher area requires a number of improvement in usefulness and ease of use in future versions of A to Z Safari. To improve usefulness and allow the teachers to integrate assessment feedback into their weekly

teaching, data analytics need to provide multiple and customisable views. Both teachers commented on the need for quick and easy feedback within the app from both the macro (class) level as well as micro (student) level. While data export features remain, it is the ability for quick feedback that could be better integrated into A to Z Safari to improve classroom integration.

8. Conclusion and future work

The evaluation of A to Z Safari, based on user statistics and teacher interviews, demonstrated ease of use and usability of the app. Further, the evaluation helped to understand how the research based approach impacted upon the design and development of A to Z Safari. Usefulness and ease of use of TAM, used to evaluate A to Z Safari, proved effective to determine usability and inform app updates. While this paper does not address the educational outcomes of student use of A to Z Safari, the results show support for the unique presentation of letter-sound associations (Nicholas et al., 2017).

Overall, the results in this paper suggest that A to Z Safari provided a usable and educational app for learning letter-sound associations. However evaluation uncovered a number of ways in which both the usability and educational components could be improved for future use. Improvements included: updating content design for certain letter tiles (for example 'U'), consideration of projected sounds while in a classroom environment, ability to review letter-sound combinations outside of gameplay, clear student and teacher tutorials to assist first time users, and improvements to the teacher area to provide quicker and customisable access to visualisation of data on both a macro (class) and micro (student) level.

When designing an educational app for young children, recommendations in regards to content, interaction and learning should be strongly considered through all stages of development. This research uncovered the importance of observing use of apps in the classroom environment to determine what modes of communication (e.g. aural, visual,) are best suited to support learning. In addition our work asserted a need for data capturing facilities to be 'designed into the background' to support learning analytics (Reid and Ostaszewski, 2011). This is critical, as the use of digital applications in the classroom will be determined not merely on accessibility, but by their adoption by those who intend to use these tools to facilitate learning: both principals (headmasters) and classroom teachers (De Grove et al., 2012, Flewitt et al., 2014, Reid and Ostaszewski, 2011).

References

- Agramonte, V. & Belfiore, P. J. 2002. Using mnemonics to increase early literacy skills in urban kindergarten students. *Journal of Behavioural Education*, 11, pp.181-190.
- Apple Press Info. 2013. *Itunes u content tops one billion downloads* [Online]. Apple. Available: <https://www.apple.com/pr/library/2013/02/28iTunes-U-Content-Tops-One-Billion-Downloads.html> [Accessed 11th January 2017].
- Australian Government. 2005. *Teaching reading - report and recommendations – national inquiry into the teaching of literacy* [Online]. Australian Government: Department of Education, Science and Training [Accessed].
- Bellezza, F. S. 1981. Mnemonic devices: Classification, characteristics, and criteria. *Review of Educational Research*, 51, pp.247-275.
- Burgess, S. R. & Lonigan, C. J. 1998. Bidirectional relations of phonological sensitivity and prereading abilities: Evidence from a preschool sample *Journal of experimental child psychology*, 70, pp.117-141.
- Busch, C., Claßnitz, S., Selmanagić, A. & Steinicke, M. 2015. Developing and testing a mobile learning games framework. *Developing and Testing a Mobile Learning Games Framework*, 13, pp.151-166.
- Danker, J. F., Fincham, J. M. & Anderson, J. R. 2011. The neural correlates of competition during memory retrieval are modulated by attention to the cues. *Neuropsychologia*, 49, pp.2427-2438.
- Davis, F. D., Bagozzi, R. P. & Warshaw, P. R. 1989. User acceptance of computer technology: A comparison of two theoretical models. *Management Science* 35, pp.982-1003
- De Graaff, S., Bosman, A. M., Hasselman, F. & Verhoeven, L. 2009. Benefits of systematic phonics instruction. *Scientific Studies of Reading*, 13, pp.318-333.
- De Graaff, S., Verhoeven, L., Bosman, A. M. T. & Hasselman, F. 2007. Integrated pictorial mnemonics and stimulus fading: Teaching kindergartners letter sounds. *British Journal of Educational Psychology*, 77, pp.519-539.
- De Grove, F., Bourgonjon, J. & Van Looy, J. 2012. Digital games in the classroom? A contextual approach to teachers' adoption intention of digital games in formal education. *Computers in Human behavior*, 28, pp.2023-2033.
- Department of Education and Training 2016. Evaluation of the early learning language australia trial. Deloitte Access Economics.
- Dewey, J. 1938. *Experience and education*, New York Collier.

- Dilorenzo, K. E., Rody, C. A., Bucholz, J. L. & Brady, M. P. 2011. Teaching letter–sound connections with picture mnemonics: *Itchy's alphabet* and early decoding. *Preventing School Failure*, 55, pp.28-34.
- Dsp Learning Pty Ltd 2012. Oz phonics bundle. Apple.
- Edoki Academy. 2014. *Montessori letter sounds* [Online]. Apple. Available: <https://itunes.apple.com/au/app/montessori-letter-sounds-phonics/id479243891?mt=8> [Accessed 30th August 2017].
- Ehri, L. C., Deffner, N. D. & Wilce, L. S. 1984. Pictorial mnemonics for phonics. *Journal of Educational Psychology*, 76, pp.880-893.
- Etherington, D. 2013. *Apple has sold over 8m ipads direct to education worldwide, with more than 1b itunes u downloads* [Online]. Available: <https://techcrunch.com/2013/02/28/apple-has-sold-over-8m-ipads-direct-to-education-worldwide-with-more-than-1b-itunes-u-downloads/> [Accessed 11th January 2017].
- Flewitt, R., Messer, D. & Kucirkova, N. 2014. New directions for early literacy in a digital age: The ipad. *Journal of Early Childhood Literacy*, pp.1–22.
- Fulk, B. M., Lohman, D. & Belfiore, P. J. 1997. Effects of integrated picture mnemonics on the letter recognition and letter-sound acquisition of transitional first-grade students with special needs. *Learning Disability Quarterly*, 20, pp.33-42.
- Furió, D., González-Gancedo, S., Juan, M. C., Seguí, I. & Rando, N. 2013. Evaluation of learning outcomes using an educational iphone game vs. Traditional game. *Computers & Education*, 64, pp.1-23.
- Gelo, O., Braakmann, D. & Benetka, G. 2008. Quantitative and qualitative research: Beyond the debate. *Integrative Psychological and Behavioral Science*, 43, pp.266-290.
- Henderson, S. & Yeow, J. 2012. Ipad in education: A case study of ipad adoption and use in a primary school. *45th International Conference on System Science (HICSS)*, 4-7 Jan. Hawaii: IEEE.
- Hoogeveen, F. R., Smeets, P. M. & Lancioni, G. E. 1989. Teaching moderately mentally retarded children basic reading skills. *Research in Developmental Disabilities*, 10, pp.1-18.
- Jones, D. 2009. A history of technology-mediated learning. *The Weblog of (a) David Jones: A pessimistic optimist's journey through learning, teaching and technology*.
- Kirriemuir, J. & McFarlane, A. 2006. Literature review in games and learning report 8. *Futurelab Series*.
- Kline, L. W. 1921. An experimental study of associative inhibition. *Journal of Experimental Psychology*, 4, pp.270-299.
- Kress, G. & Leeuwen, T. V. 2001. *Multimodal discourse: The modes and media of contemporary communication*, New York, Oxford University Press.
- Kuo, M.-L. A. & Hooper, S. 2004. The effects of visual and verbal coding mnemonics on learning chinese characters in computer-based instruction. *Educational Technology, Research and Development*, 52, pp.23-38.
- Levin, J. R. 1993. Mnemonic strategies and classroom learning: A twenty-year report card. *The Elementary School Journal*, 94, pp.235-244.
- Livingstone, S. & Smith, P. K. 2014. Annual research review: Harms experienced by child users of online and mobile technologies: The nature, prevalence and management of sexual and aggressive risks in the digital age. *Journal of child psychology and psychiatry*, 55, pp.635-654.
- Lynch, J. & Redpath, T. 2012. Smart technologies in early years literacy education: A meta-narrative of paradigmatic tensions in ipad use in an australian preparatory classroom. *Journal of Early Childhood Literacy*, 14, pp.147-174.
- Manalo, E., Uesaka, Y. & Sekitani, K. 2013. Using mnemonic images and explicit sound contrasting to help japanese children learn english alphabet sounds. *Journal of Applied Research in Memory and Cognition*, 2, pp.216-221.
- Marchetti, E. & Valente, A. 2015. Learning via game design: From digital to card games and back again. *The Electronic Journal of e-Learning*, 13, pp.167-180.
- Melby-Lervåg, M., Lyster, S.-a. H. & Hulme, C. 2012. Phonological skills and their role in learning to read: A meta-analytic review. *Psychological bulletin*, 138, pp.322.
- Mifsud, L. 2002. Alternative learning arenas-pedagogical challenges to mobile learning technology in education. *IEEE International Workshop on Wireless and Mobile Technologies in Education*, 29-30 Aug. 2002. Växjö, Sweden: IEEE.
- National Early Literacy Panel 2008. Developing early literacy: Report of the national early literacy panel. *A Scientific Synthesis of Early Literacy Development and Implications for Intervention*. Jessup, MD: National Institute for Literacy.
- National Reading Panel 2000. Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction: Reports of the subgroups. In: Development, N. I. O. C. H. a. H. (ed.).
- Nicholas, M., McKenzie, S. & Wells, M. A. 2017. Using digital devices in a first year classroom : A focus on the design and use of phonics software applications. *Journal of education and learning*, 6, pp.267-282.
- Paivio, A. & Csapo, K. 1973. Picture superiority in free recall: Imagery or dual coding? *Cognitive Psychology*, 5, pp.176-206.
- Perfetti, C. A., Beck, I., Bell, L. C. & Hughes, C. 1987. Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly*, 1987, pp.283-319.
- Pfost, M., Hattie, J., Dörfler, T. & Artelt, C. 2013. Individual differences in reading development a review of 25 years of empirical research on matthew effects in reading. *Review of Educational Research*.
- Reid, D. & Ostashewski, N. Ipad in the classroom—new technologies, old issues: Are they worth the effort? World Conference on Educational Multimedia, Hypermedia and Telecommunications, 2011 Chesapeake, VA. AACE, pp.1689-1694.
- Rieben, L. & Perfetti, C. A. 2013. *Acquisition of reading competence. Learning to read: Basic research and its implications*, Routledge.

- Rutledge-Taylor, M. F., Kelly, M. A., West, R. L. & Pyke, A. A. 2014. Dynamically structured holographic memory. *Biologically Inspired Cognitive Architectures*, 9, pp.9-32.
- Sadoski, M. & Paivio, A. 2013. *Imagery and text :A dual coding theory of reading and writing*, New York, Routledge.
- Sener, U. & Belfiore, P. J. 2005. Mnemonics strategy development: Improving alphabetic understanding in turkish students, at risk for failure in efl settings. *Journal of Behavioural Education*, 14, pp.105-115.
- Shmidman, A. & Ehri, L. 2010. Embedded picture mnemonics to learn letters. *Scientific Studies of Reading*, 14, pp.159-182.
- Stanovich, K. 1986. Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly*, 21, pp.360-407.
- Stern, J. Digital classroom magazines: Design considerations for young learners. CHI'14 Extended Abstracts on Human Factors in Computing Systems, 2014 Toronto, Canada. Canada: ACM, pp.921-926.
- Van Dyke, J. A. & Johns, C. L. 2012. Memory interference as a determinant of language comprehension. *Language and linguistics compass*, 6, pp.193-211.
- Watlington, D. Using ipod touch and ipad educational apps in the classroom. Society for Information Technology & Teacher Education International Conference, 2011 United States. pp.3112-3114.