Apps for Mathematics Learning: A Review of 'Educational' Apps from the iTunes App Store

Kate Highfield
Macquarie University
<kate.highfield@mq.edu.au>

Kristy Goodwin
Every Chance to Learn
<kristy@everychancetolearn.com>

Increasingly iPads™ are being used in schools and prior-to-school settings, with a plethora of Apps available for mathematics learning. Despite the growing number of Apps available in the iTunes App Store, there has been limited systematic analysis of the pedagogic design of Apps designed for mathematics learning. This paper describes a content analysis of Apps that are currently available as 'educational' content in the iTunes App Store and highlights the limited range of pedagogic designs available for mathematics learning.

Increasingly mobile touch devices, such as the iPhone, iPod touch and iPads, are suggested as tools for mathematics learning (McKenna, 2012). This is particularly relevant in the early years of schooling where teachers perceive these as valid pedagogical devices (Olney, Herrington, & Verenikina, 2008) that are engaging for learners (McKenna, 2012). In part, this is because these devices compensate for the fine motor skills required to operate traditional computers with a mouse. Here we see that the direct touch interface and gestural actions allow children to easily manipulate and interact with screen objects and create digital content. Further, the mobile nature of these devices affords cost-effective use in multiple contexts, rather than in just one curriculum area (Aronin & Floyd, 2013) or in a computer laboratory or fixed position in the classroom. The Michael Cohen Group LLC (2011) suggests that some Apps designed for use on these devices allow young children to learn and discover in ways that are commensurate with their preferred learning modes: physical touch, trial and error, and repetition. These attributes, combined with the relatively low cost options available, appear to make touch devices an appealing platform and may account for educators' increasing embrace of these technologies.

Background

Whilst there is emerging research examining the effectiveness of mobile Apps (PBS Kids, 2010, S huler, 2009), much of the research has been conducted by large media organisations or focuses on case study trials of devices. In mathematics education there is limited, but growing corpus of research outlining the use of Apps and accompanying pedagogies. However, studies examining these tools in mathematics education are beginning to highlight the potential of specific Apps for learning or examine integration of these technologies (Aronin & Floyd, 2013; Attard & Curry, 2012; Kiger, Herro & Prunty, 2012; McKenna, 2012). Despite the limited research, these devices can be seen to afford visual representations that are essential for communicating ideas and concepts (Goldin & Kaput, 1996). Further, as with other technologies, these tools offer new affordances for representation (Highfield & Mulligan, 2007; Moyer, Niezgoda & Stanley, 2005) and engagement in dynamic representations (Goodwin, 2009).

A content analysis of the App store shows that a significant proportion of the top 100-selling Apps (for iPhone and iPod touch devices) in the United States are designed for preschool or primary aged children. This analysis by Shuler's (2009) found that 47% of most popular Apps are designed for these age groups. Shuler's (2009) analysis, consistent with the later work of Watlington (2011), found that foreign language and literacy the most

In V. Steinle, L. Ball & C. Bardini (Eds.), Mathematics education: Yesterday, today and tomorrow (Proceedings of the 36th annual conference of the Mathematics Education Research Group of Australasia). Melbourne, VIC: MERGA.

popular curriculum areas supported by Apps. Watlington's (2011) work extended beyond a content analysis to examine appropriateness of these tools. This study used the Haughland Developmental Software Scale (1998) to rate the developmental appropriateness of free iPad Apps' and found that only 48% of the Apps analysed were classified as developmentally appropriate and recommended for educational use (Watlington, 2011). These findings highlight the need for critical review of Apps being promoted as educationally appropriate for children.

Given that anecdotal reports suggest that teachers and parents most frequently look for Apps for children in the 'Education' section, a systematic analysis of the content and pedagogical design of Apps included in this category is warranted. Further, analysis of Apps purchased in this category may provide insight into educational decisions made by parents and educators. By examining the underpinning pedagogies inherent in Apps purchased, some insight into pedagogical approaches employed by these new technologies can be gained. This study moves beyond 'market research' type analyses, which focussed on content alignment by age and or curriculum area. With the exception of analyses by the authors of this paper (Goodwin & Highfield, in press), there appears to be no research that examines the pedagogic elements that underpin the design of Apps.

The purpose of this paper was to examine the most popular Apps in the 'education' section of the App store in the United States, United Kingdom and Australia and to respond to the following research questions:

1. To what extent do popular Apps cater for a range of age groups?
2. What is the distribution of curriculum content in popular paid Apps?
3. To what extent is a range of pedagogies reflected in App store purchases?
4. What pedagogic designs are specifically included in Apps designed for mathematics learning?

Method

As outlined the current project consisted of a systematic analysis of most popular Apps from the 'Education' education section of the iTunes App Store at six-monthly intervals from April 2010 to October 2012. Popular Apps were seen as the most downloaded, with the top ten downloaded Apps identified at each of these time periods. An aggregate data analysis website was used initially to ascertain these, with downloads verified by the analytic data available from the iTunes App Store. Within this study Apps purchased in three broadly comparable English-Speaking countries were compared, with data collated from the United States of America, the United Kingdom and Australia.

This project focussed solely on pa id Apps suitable for use on Apple touch screen devices, specifically the iPad, iPhone and iPod touch. While the researchers acknowledge that there are many high-quality free Apps available it is suggested that approximately 65% of these adopt a "freemium" model where 'lite' versions (with limited functionality) are presented (Watlington, 2011). Given the restricted nature of these 'lite' Apps this study focuses on 'full' or paid versions ensuring a complete examination of content was possible. The researchers further acknowledge that there are a range of other touch and tablet devices available to children. However, at the commencement of data collection the App store dominated the education market and so, for pragmatic reasons, became the focus of this study.

Once the popular Apps (n = 360) were identified each was coded: by Age, Curriculum Content and Pedagogic Design.

Each App was first classified by *Age*, where the specified age of the target user was ascertained from the App description. Where an age group was not specified a researcher independently nominated an appropriate age group based on de sign and content. The second researcher then independently verified age coding for Apps. The classifications were: Toddler (Birth-5 years), primary (6-12 years), secondary (13 years plus) and multi-age, with multi-age Apps having the potential for use across multiple age ranges.

Each App was then classified by *Curriculum Content*. Within this classification ten curriculum areas were identified:

1. Mathematics,
2. Literacy (encompassing Language Arts),
3. Foreign Language,
4. Creative and practical Arts (which also included Music and Drawing Apps),
5. Science,
6. History,
7. Geography,
8. Economics,
9. General Learning (this includes Life Skills such as ‘UK Car Driving Theory’) and
10. Multiple Curriculum Areas (for example, when numeracy and literacy activities were included within the one App).

Finally, each App was classified by *Pedagogical Design*. Here each App was examined and classified according to its underpinning pedagogic elements and design features. This classification was based on coding used to analyse interactive multimedia (Goodwin, 2009; Goodwin & Highfield, in press). Here, three broad classifications are adopted, based on the learner’s locus of control over the activities, representations presented in the App and the user’s level of cognitive investment. The three broad classifications on this continuum include: instructive, manipulable and constructive. Following initial classification two other sub-categories emerged: constructive/manipulable and manipulable/instructive instructive Apps. Apps within these latter categories contain a hybrid of pedagogical design, incorporating elements from both classifications. Analysis of the pedagogical design provides an opportunity to consider the underpinning pedagogies and to suggest placement of these designs along a continuum. Further information on this continuum can be found in Goodwin (2009) and Goodwin and Highfield (in press). Figure 1 pr esents a visual overview of this continuum.

Figure 1. Overview of the pedagogic design continuum.

Instructive Apps have elements of ‘drill-and-practice’ design, whereby the App contains a predetermined ‘task’ where a homogenous response is required from the user. These Apps generally require minimal cognitive investment on behalf of the learner and are frequently based on behaviourist concepts and use extrinsic rewards. “Math Bingo” by ABCya.com and “Quick Math” by Shiny Things are presented in the discussion section as exemplars of instructive pedagogic design.

The second pedagogic design category is manipulable. This group of Apps is based on design structures that allow the user to manipulate elements, enabling guided discovery and experimentation within a pre-determined context or framework. These Apps generally require more cognitive investment than instructive Apps, but less than constructive Apps. While some Apps in this category require correct answer to complete a task, these Apps provide flexible solution strategies and/or manipulable representations. An example of a manipulable tool is "Pick-a-Path" by the National Council of Teachers of Mathematics is presented in the discussion section as an exemplar of the manipulable pedagogic design category.

Constructive Apps are characterised by a more open-ended design this allows users to create content and digital artefacts. Open-ended drawing Apps are emblematic of Constructive Apps, these Apps generally don't utilise extrinsic rewards and provide the user opportunities for choice and creativity. "Explain Everything" by Morris Cooke and "My story" by HiDef Web Solutions are examples of this pedagogical design.

Results and Discussion

Examination of Age and Curriculum Content

Analysis indicated that Apps catering to a range of age groups are represented in the top ten Apps in the 'education' section of the App store. Data, aggregated over each of the data collection points, indicates that 29% of the Apps were designed to cater children in prior to school settings, 24% for primary aged children and only 13% were designed for secondary education. A large proportion (34%) were classified as 'Multi-age', that is suitable for use across a range of children. These findings reflect a similar analysis by Shuler (2012).

An examination of Age by each country is presented in Figure 2. Here data from Australia indicates that classification of 'education' Apps by age groups is more aligned with data from the United States of America. Data from the United Kingdom suggests a preference for tools used by multiple age groups and designed for older children, with fewer Apps in the 'education' section designed for toddlers in prior-to-school settings.

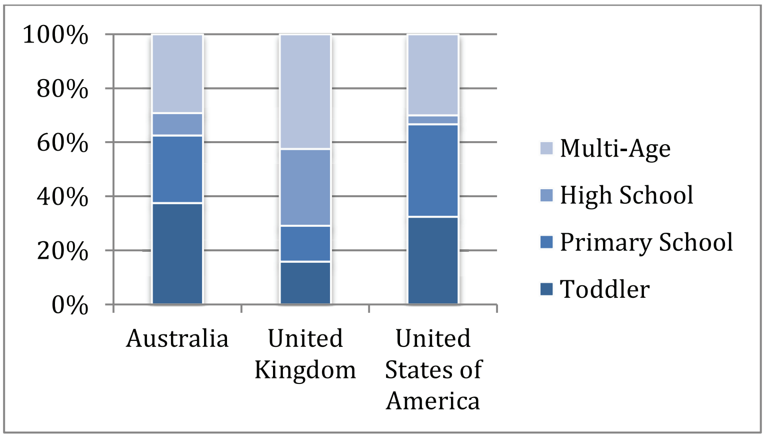

Figure 2. Classification of Apps by age group, comparing data from three countries.

An examination of Apps according to curriculum content showed a limited range of curriculum areas. Figure 3 provides an overview of 'education' Apps, as classified by curriculum area. Analysis of each country reveals similar results and aggregated data for the three countries indicates that while 21% of Apps in this study focus on Literacy content and 19% on Science content only 15% of the top ten Apps from these data collection points focus expressly on Mathematics content and processes. In making this statement it should be acknowledged that many other Apps embed mathematical content, such as totalling scores to identify a winner. However, only Apps where mathematics content was the clear educational focus are included in this category. Further to this, 18% of these 'education' Apps address multiple curriculum areas (for example literacy and numeracy). Here it is noteworthy that Apps for history and geography reflect less than 1% of those popular in the 'education' section of the App store.

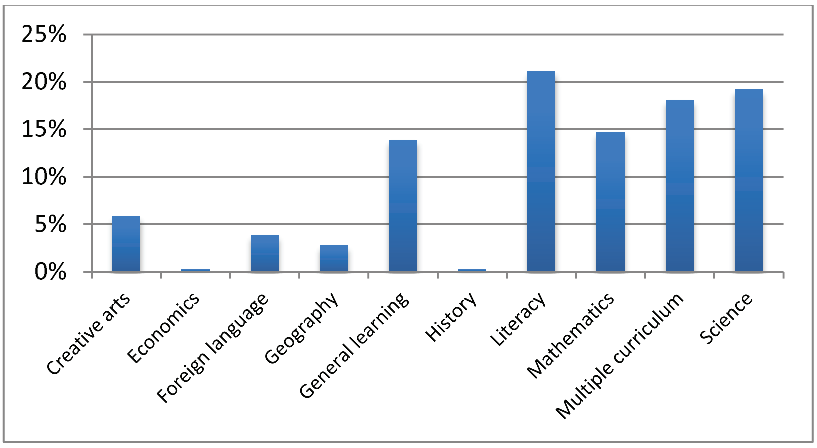

Figure 3. Classification of Apps by curriculum area.

Examination of Pedagogic Design

Classification of educational Apps by pedagogic design indicates predominance of instructive Apps. Here 74% of educational Apps were categorised as instructive, with a further 11% combining elements of instructive and manipulable design pedagogies. Ten percent of Apps were classified as manipulable and only 1% were placed in the constructive category. An additional 3% can be seen to combine elements of constructive and manipulable design approaches.

As outlined, 15% (n=53) of the top 'education' Apps focussed on mathematics learning. Of the mathematics Apps, analysis by pedagogic design revealed that the most prevalent design was instructive (n=47), with a focus on "drill and practice" type activities. The remainder (n=6) of the Apps with a specific mathematical focus integrated manipulable and instructive components. No mathematical Apps in this data set demonstrated constructive pedagogic design principles. Some examples of Apps for each pedagogic design classification are described in the following sections.

"Math Bingo" (ABCya.com) and "Quick Math" (Shiny Things) are examples of instructive Apps. Both "Math Bingo" (ABCya.com) and "Quick Math" (Shiny Things) are designed for primary aged children and both provide opportunity for the user to practice equations for addition, subtraction, multiplication and division. They are also similar in that they provide three levels of practice, from simple, single digit equations to two digit equations. Both have a pedagogic focus on quick repetition of facts the apparent goal of developing computational fluency. As shown in Figure 4, "Math Bingo" (ABCya.com) relies on the user selecting the correct response to the equation, by touching the correct answer from a board of possible responses. Correct answers are rewarded with a 'positive' sound and incorrect responses with a negative 'buzz'. Users who correctly complete a line of equations, thus forming "bingo", without an error are rewarded by a "bingo bug" an animated sticker. "Math Bingo" (ABCya.com) games are accompanied by a repetitive piece of synthesised music. “Quick Math” (Shiny Things) is also an example of an instructive design, as it requires the user to respond to a set collection of questions. This App has a different mode of response, with the user using their finger to write the numeral on the screen, as evidenced in Figure 5 (below). This App does not utilise substantial overt rewards, but instead graphs the user’s fluency in comparison to previous attempts.

Figure 4. A screen shot of “Math Bingo” (by ABCya.com), an example of an instructive App.

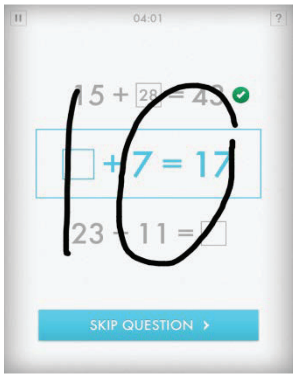

Figure 5. A screen shot of “Quick Math” (by Shiny Things), an alternate example of an instructive App.

Of the ‘education’ Apps for mathematics learning, most instructional Apps focus on the user engaging with one key skill at a time. Here content acquisition is seen as paramount with the user’s engagement in mathematical processes (such as problem solving and communication) given less emphasis.

Within this data set no Apps for mathematics learning were classified as having a manipulable pedagogic design, with only few (n=6) mathematics Apps incorporating components of manipulable and instructive design. One example of a manipulable App, (although not included the current data for popular Apps) is “Pick-a-Path” (by the National Council of Teachers of Mathematics). This App provides opportunity to focus on mathematical processes in tandem with mathematical content, as the manipulable nature of engagement promotes decision-making opportunities. In “Pick-a-Path” (National Council of Teachers of Mathematics) learners are required to select alternate pathways of equations to meet a set goal, with multiple solutions possible. As demonstrated in Figure 6, here the user has the goal of gaining the highest maximum score and has to choose a path of equations to attain that goal. To successfully complete this game the user has to demonstrate mathematical content skills, but rather than simply choosing one answer the user has to critically reflect on the options, applying strategies to select the best of a set of options. While computational fluency is still practiced within this App, higher order learning processes are required as users make critical selections.

It was not surprising that there were no examples of constructive design within the top ten mathematics Apps in this data set. In part this is because of the open-ended nature of these Apps, where they are more likely to be aligned to multiple curriculum areas. Additionally, this could be because constructive Apps have not yet been conceptualised developers of Apps. “My story” by HiDef Web Solutions is one of a few examples of a constructive pedagogic design. In the example shown in Figure 7 a user has begun to create a storybook of ways to make 10. Here there is no set right or wrong answer, merely an opened-ended capacity to represent ideas. Further, as constructive tools afford multiple representational opportunities, this means that teachers have the potential to design tasks across multiple curriculum strands, skills and processes.

Figure 6. A screen shot of "Pick-a-Path" (by the National Council of Teachers of Mathematics) an alternate example of a Manipulable App.

Figure 7. A screen shot of a story created with "My story" by HiDef Web Solutions.

Given that open-ended learning and representation are essential to foster young children's creativity and thinking skills, the limited representation of constructive Apps in the 'Education' category is of concern. Similarly, the prevalence of instructional 'educational' Apps for mathematics learning raises serious questions about promoting current knowledge about mathematical learning. There are several plausible explanations that may possibly account for this finding. Firstly, it is possible that App developers are demonstrating an entrenched philosophical position of what constitutes mathematics learning, i.e., as a set of 'drill-and-practice' tasks focused on computation. Alternately these Apps may be popular with parents and educators as they generally link with specific curriculum goals, practising specific skills. Many of these Apps align with a behaviourist position and may replicate the developers' personal school experiences or may indicate a preference from parents for more traditional 'drill-and-practice' type activities. Alternatively, the linear and prescriptive design, with answer and response design mechanics, may be easier for developers to program.

Conclusions and Implications

These data provide evidence of the need for a broader range of Apps for mathematics learning and highlight the importance of App developers designing Apps that promote manipulable and constructive opportunities for representation of mathematical concepts.

A limitation of this project was its focus on one media platform; Apps designed for use on Apple touch screen devices from three English speaking countries and that the content analysis was restricted to the 'top ten' Apps in the 'education' section of the App store. However, given that there were over 775,000 Apps available in December 2012 and that over 40 billion Apps have been downloaded since 2012 (Apple Press Release, January 2013), these pragmatic decisions are justifiable.

Despite these limitations, data from this study highlight the difficulties faced by educators in accessing and critiquing 'educational' Apps. The fluid and ever-increasing nature of Apps is problematic, with the 'education' section frequently providing spurious content classified as 'educational'. The limited range of mathematics Apps is compounded by the limited pedagogic design choices available for educators. While these data highlight the sustained popularity of instructional apps, they may also highlight a misunderstanding among parents who see "drill-and-practice" mathematics learning as more beneficial than problem-solving tasks. Education of parent communities, who are largely responsible for App purchases, needs to emphasise the benefits of Apps beyond "drill-and-practice" instructional tools. Further, teachers need to be able to access a range of Apps to facilitate alignment of pedagogic approaches to technology tools. This is particularly relevant given that different design pedagogies may be appropriate across for different mathematical skills and processes.

Finally, this project highlights the need for further research examining the use of Apps for mathematics learning, beginning with young children in home and school settings. Studies are required to examine the impact of pedagogical design on mathematics learning and achievement and on teachers' knowledge of pedagogic approaches and alignment between technological tools and classroom activities.

References

Apple Press Release (2013). *App Store Tops 40 Billion Downloads with Almost Half in 2012.* Retrieved 20 March, 2013, from http://www.apple.com/pr/library/2013/01/07App-Store-Tops-40-Billion-Downloads-with-Almost-Half-in-2012.html

Aronin, S., & Floyd, K. (2013). Using an iPad in inclusive preschool classrooms to introduce STEM concepts. *Teaching Exceptional Children 45,* 4, 34-39.

Attard, C., & Curry, C. (2012), Exploring the use of iPads to engage young students with mathematics, In J. Dindyal, L. P. Cheng & S. F. Ng (Eds.), *Mathematics education: Expanding horizons (Proceedings of the 35th annual conference of the Mathematics Education Research Group of Australasia).* Singapore: MERGA.

Goldin, G. A., & Kaput. J. J. (1996). A joint perspective on the idea of representation in learning and doing mathematics. In P. Steffe (Ed.), *Theories of Mathematical Learning* (pp. 397-431). New Jersey: LEA.

Goodwin, K. (2009). *Impact and affordances of interactive multimedia,* Unpublished doctoral dissertation, Macquarie University, Sydney.

Goodwin, K & Highfield (in press). A framework for examining technologies and early mathematics learning. In L. D. English and J. T. Mulligan (Eds.), *Reconceptualising early mathematics learning.* New York: Springer.

Haugland, S.W. (1998) The best developmental software for young children. *Early Childhood Education Journal, 25*, 4, 247-254.

Highfield, K., & Mulligan, J. T. (2007). The role of dynamic interactive technological tools in preschoolers' mathematical patterning. In J. Watson, & K. Beswick (Eds.), *Paper presented at the 30th Annual Conference of the Mathematics Education Research Group of Australasia*, (Vol. 1, pp. 372-381). Tasmania: MERGA inc.

Kiger, D., Herro, D., & Prunty, D. (2012). Examining the influence of a mobile learning intervention on third grade math Achievement. *Journal of Research on Technology in Education*, *45*(1), 61-82.

Michael Cohen Group LLC (2011). *Young children, Apps and iPad* (Research undertaken as part of the US Department of Education Ready to Learn Program). Retrieved 16 July 2011, from http://www.mcgrc.com/wp-content/uploads/2011/07/iPad-study-cover-page-report-mcg-info_new-online.pdf.

McKenna, C. (2012). There's an App for that: How two elementary classrooms used iPads to enhance student learning and achievement. *Education*, *2*(5), 136-142.

Moyer, P., Niezgoda, D., & Stanley, M. (2005). Young children's use of virtual manipulatives and other forms of mathematical representation. In W. Masalski & P. Elliott (Eds.), Technology-supported mathematics learning environments (pp. 17-34). Reston, VA: NCTM.

Olney, I., Herrington, J., & Verenikina, I. (2008). iPods in early childhood: mobile technologies and story telling. In Hello! Where are you in the landscape of educational technology? *Proceedings Ascilite Melbourne 2008*. http://www.ascilite.org.au/conferences/melbourne08/procs/olney.pdf.

PBS Kids, (2010). *There's an App for that.* PBS Kids. Retrieved 18 October 2011, from pbskids.org/read/files/cooney_learning_apps.pdf

Shuler, C. (2009). iLearn; *A content analysis of the iTunes App store's education section*, New York: The Joan Ganz Cooney Center at Sesame Workshop.

Takeuchi, L. M. (2011). *Families matter: designing media for a digital age*. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Watlington, D. (2011). Using iPod touch and iPad educational Apps in the classroom. In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2011* (pp. 3112-3114). Chesapeake, VA: AACE.