Children and Mobile Apps for Learning

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Abstract. With the rapid proliferation of mobile devices, and the widespread adoption of mobile apps, there has been keen interest from both parents and teachers in using mobile devices as tools to support children learning. The popularity of educational apps targeted at children has created lucrative opportunities for app designers. However, there has been a lack of established theoretical frameworks for understanding and analyzing the unique design considerations for designing learning apps for children. In this paper, we have conducted an extensive review of existing literature to develop a holistic approach to understanding the design considerations required for creating mobile learning applications for children. The 3 major areas we identified were: Design Considerations for Mobile, Design Considerations for Children, and Design Considerations for Education. Through our case study of the 2 apps "Peekaboo Moona" and "Duolingo", we then analyzed and exemplified the practical implications of the 3 major design considerations using real world applications.

1. Introduction

As of June 2016, Apple's App Store had exceeded 130 billion apps downloaded since its inception, with a total of more than 2 million apps currently available for download (Perez, 2016). With the proliferation of mobile devices and widespread adoption of mobile apps, teachers and parents are beginning to turn to mobile devices as important tools in supporting the education of children (Olney, Herrington, & Verenikina, 2008). According to recent research, 80 percent of the popular paid apps belong to the education category with children as their main audience (Carly Shuler, Zachary Levine, Jinny Ree, 2012). This presents lucrative opportunities for app designers to leverage on trends and develop innovative and unique solutions to enhance the mobile learning experience for children.

However, despite the abundance of apps currently available for children on the app store, there has been a lack of consensus on an established theoretical framework for analyzing and understanding the design considerations involved in the creation of these apps. Therefore, the objective of this research is to develop a holistic approach for understanding the design considerations required for designing mobile learning applications for children. Through the lens of this holistic approach, we will also analyze and exemplify how these design considerations are being implemented in real world applications. In the first portion of this paper, we will begin by reviewing relevant theories that have been put forth in the subject domain. Following which, we will take a look at case study examples of how app designers have applied these design considerations.

2. Literature Review

Two of the important pillars of designing interactive systems are: designing for usability, and designing for usefulness (Rogers, Sharp, & Preece, 2011). In order to address these design areas, we are required to comprehend the nuances in the diversity and needs of our target audience, and how systems effectively fulfil their intended uses. Therefore, we shall be reviewing existing literature to develop a model that helps us better understand the considerations involved in designing learning apps for children.

2.1 Design Considerations for Mobile

Mobile devices such as smartphones are highly portable computers that possess relatively small screen sizes, with only touchscreen or stylus input methods (Huang, 2009). Mobile applications (apps) are the small lightweight programs running on mobile devices, providing a range of services including entertainment, web surfing, educational learning and GPS navigation (Shin & Shin, 2011). They have been adopted and are used worldwide by people of different cultures, knowledge backgrounds and learning abilities (Blok, 2010). This hence presents a unique challenge where app designers not only need to design around the constraints of the mobile device, but also need to understand and tailor experiences for a global audience.

The physical limitations of mobile devices bring about a fundamental set of considerations that app designers need to account for. Designing apps for mobile devices differs greatly from designing programs for stationary desktop computers as the mobile devices are restricted in terms of their screen sizes, battery, input facilities, and network connectivity (Huang, 2009).

2.1.1 Screen Size

The relatively smaller screens on mobile devices serve as an important factor to consider when designing interfaces to present information to users. Due to this limitation, designers have found it challenging to design the navigational structures of apps. Information that is displayed across separate pages may become too fragmented as the user may be unable to develop an integrated mental model due to limited short-term memory (Albers & Kim, 2000).

Studies have shown that navigational activity increases significantly on smaller screens, thereby leading to lower user productivity (Jones, Marsden, Mohd-Nasir, Boone, & Buchanan, 1999). Desktop programs have expansive navigational menus that afford users with fast and efficient ways to access features. Mobile devices do not have such luxuries, and overly convoluted menus often lead users to confusion (van der Velde, et al., 2004). Hierarchical menus should therefore not contain more than four to eight items on each level to facilitate faster navigation. (Geven, Reinhard, & Tscheligi, 2006). The goal of the designer should be to reduce the need for users to scroll up and down while selecting items from a menu (Anderson, Hirsh, & Mohr, 2008), and to reduce the number of repetitive operations so as to increase the pace of user interaction (Huang, 2009). Additionally, interfaces should be designed in such a way that very little memorization is required for the performance of tasks, so as to reduce the load on short-term memory (Chan , et al., 2002).

2.1.2 Battery

Mobile devices serve various functionalities and purposes, yet they are restricted in battery capacity due to the smaller physical dimensions required to make them portable. Hence, battery life remains as one of the major considerations for application designers (Huang, 2009). The rate of power consumption in apps, depends heavily on the functionalities, performance optimization, and supporting processes implemented by app developers (Ashwini, Thawani, & Srikant , 2006). Thus, special considerations need to be put in place to ensure that the apps are designed in a way that optimizes battery life. For example, to conserve battery, apps should reduce computation, communication, and memory activity when not running in the foreground, so as to reduce performance and energy consumption overheads (Forman & Zahorjan, 1994).

2.1.3 Input Facilities

The main method of input on mobile devices is through a capacitive touchscreen. This often implies that there is a lack of precision as users are expected to perform inputs using their fingers (K. A. Siek, 2005). The implications of this is that app designers would need to take into account the minimum size of onscreen elements that the user is able to interact with. The use of a capacitive stylus could possibly alleviate this issue. However, such accessories are not commonplace (Huang, 2009).

2.1.4 Network Connectivity

The wireless networking capabilities of mobile devices allow users to have portable access to the internet as well as other online based services without being physically tethered to a connection (Malladi & Agrawal, 2002). However, such capabilities cannot be taken for granted as these devices may experience intermittent disruptions in connectivity. For example, users may move into areas with limited network coverage, resulting in a temporary breakdown of their ability to send and receive data across the network (Ioannidis , Duchamp , & Maguire, Jr., 1991). App designers hence need to accommodate this increase in volatility, and handle instances where the app is temporarily unable to synchronize information with a web server (Forman & Zahorjan, 1994).

2.2 Design Considerations for Children

With the advancement of IT, there has been a growing trend of children being engaged with different kinds of mobile apps. The nature of these children learning apps are categorised into the four types: "physical exercise games, participatory simulations, field trips and visits, content creations." (Druin, 2009) In addition, these apps provide three main benefits to children. Firstly, learning apps stimulate the interest of children to study. Secondly, it promotes flexible learning experiences outside school period. Thirdly, it enables children to acquire knowledge through different kinds of information flows. According to the recent research, 80 percent of the popular paid apps belong to the education category with children as the main audience. (Carly Shuler, Zachary Levine, Jinny Ree, 2012) These apps often build an effective user experience for children based on the three conditions: sensory motor, emotional and verbal expression. These engagement conditions are correlated to the following aspects of learning experience: cognitive, psychomotor and affective. (Krathwohl, 2010) (Figure 1)

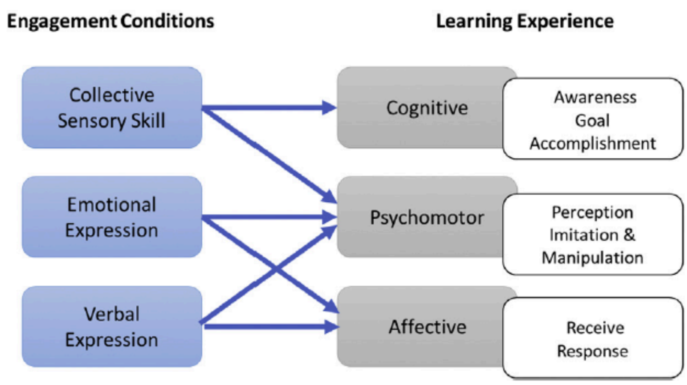

Figure 1 – "Engagement conditions of children's learning when interacting with mobile apps" (A. Noorhidawati, S.Ghazal Ghalebandi, R.Siti Hajar, 2015)

2.2.1 Cognitive

Learning through cognitive aspects requires characteristics of awareness and goal accomplishment. Children gain awareness by memorizing and comprehending the apps. Furthermore, app features like navigation and key functions help improve children's awareness by encouraging them to have more hands-on activity on the device. In addition, children show their goal accomplishment ability when they use apps to finish the assignments such as doing memory games, solving questions and reading storybooks. Thus, interactive elements and task-oriented features in apps are better appreciated by children. (A. Noorhidawati, S.Ghazal Ghalebandi, R.Siti Hajar, 2015)

2.2.2 Psychomotor

Psychomotor learning includes physical actions such as body movements, perception and manipulation. Perception is gained when children are able to respond quickly to the changes in the mobile apps. Children also demonstrate imitation and manipulation when they carry out repeated actions accurately (Krathwohl, 2010). By interacting with the apps intuitively using the touchscreen, children gain confidence and engagement with the activity involved. (Timothy L.J. Ferris, S.M. Aziz, 2015)

2.2.3 Affective

Affective learning demonstrates features of Receive and Response. Receive is showed when children are sensitive to the apps. Characteristics of this include concentration and getting interested or bored. Response is showed when children are motivated by the apps to continue and take further actions. It includes any reactions from the children when they interact with apps, for example, their facial expressions, laughing and smiling. (A. Noorhidawati et al., 2008)

According to (Kathy Hirsh-Pasek, Jennifer M. Zosh, Roberta Michnick Golinkoff, James H. Gray, Michael B. Robb, and Jordy Kaufman, 2015), education app design should encompass active involvement, intriguing content, meaningful learning and social interaction. Statistics show that more than 60 percent of education apps have features including games, puzzles and quizzes. Furthermore, (McManis, Lilla Dale, Gunnewig, Susan B, 2012) state that educational games help by masking learning objectives thereby stimulating interest in children.

2.3 Designing Apps for Education

For many years, educators have tried to leverage on the advancement of IT to enhance the learner experience (Bulman & Fairlie, 2016). However, the efforts thus far have only shown to produce mixed results (Bates & Poole, 2003). In our review of existing literature, the causes of this appears to arise from two major factors: inappropriate integration of IT and teaching methods (Sandholtz, 1997), and the lack of learner motivation (Keller & Suzuki, 2004). Instructional strategies and tools need to be based upon sound learning and cognitive theories (Bednar et al., 1995), and successful approaches require a thoughtful design of the fundamental methodologies of teaching and learning, rather than simply grafting IT onto inappropriate teaching practices. Learner engagement, also plays an important factor into ensuring that educational apps achieve their intended learning outcomes effectively (Catalano, 1999).

2.3.1 Pedagogical Design

To avoid the pitfalls of blindly applying technology to education (Bates & Poole, 2003), and to ensure that apps are built upon sound cognitive theories (Bednar et al., 1995), designers should pay attention to the pedagogies that educators use for teaching. Drawing insights from such theories, would allow app designers to better understand how apps can be designed to promote effective learning. In our review, we have identified two major schools of thought that present vastly different approaches to education. On one hand, we have the more traditional teacher-centered (Brown K. L., 2003) model of education, and on the other hand we have the learner-centered (Altan & Trombly, 2001) model which presents a more contemporary approach to education.

It has been observed, that a large majority of classroom teaching follows the traditional teacher-centered model of education (Halpern, 1994). Such methods of instruction usually involve teachers conveying information through lectures, using textbooks to structure linear lesson plans, and learners passively receive information from the instructors (Toh, 2009). It is assumed that all educational procedures are linear and rational in nature (Catalano, 1999), the type, scope, and order of knowledge conveyed is solely determined by the teacher (Mascolo, 2009). The teacher-centered model, derives its roots from objectivist theories. Objectivists believe that teaching refers to the transmission of knowledge, and the ways in which a teacher would accomplish this is to decide for learners, based on their experience, the type of information to acquire, and how to go about acquiring them (Jonassen, 1991). Thus, the goal of the teacher-centered paradigm is to focus on the transfer of knowledge from teachers to learners. Knowledge is broken into discrete units of information and delivered by the instructor to learners who are expected to passively absorb the knowledge so that they can remember them in tests (Saulnier et al., 2008).

This linear approach better enables educators to make learning outcomes more apparent (Kinchin et al., 2008), and allows instructors to efficiently cover a fixed set of materials. However, there are several important limitations of the teacher-centered approach. The passive nature of learning assumes that learners accept all of the information taught to them, and that they all gain the same understanding and pick up knowledge in identical ways (Jonassen, 1991). From our review in Section 2.1, we know that this is not the case as users come from different backgrounds with different amounts and types of prior knowledge. Additionally, the teacher-centered approach inherently does not promote problem-based learning, which plays an important role in the cultivating of higher order thinking skills (Hmelo & Ferrari, 1997).

Recognizing the limitations of the traditional teacher-centered model, and searching ways to promote active learning, collaborative learning, and problem-based learning, as well as to focus more on the learning processes of learners, researchers over the past decades have conceptualized a learner-centered model of education. The American Psychological Association derived a set of 14 principles to serve as a framework for implementing the learner-centered model of education (APA, 1997). These 14 principles are categorized into 4 main factors, as summarized in Appendix A. The learner-centered model of education, derives its roots from constructivist theories. Constructivists believe in recognizing the learner as an active individual who possesses prior experience, beliefs and perceptions as opposed to a blank slate that needs to be molded by teacher instruction (Stevick, 1980). Hence, focus is shifted from the transfer of information, to the process of learners constructing, reorganizing and sharing knowledge (Reinders, 2010). This is in contrast with objectivist theories, where learners are not encouraged to make their own observations (Jonassen, 1991). A comparison of the differences in the two approaches is summarized in Appendix B.

Educators in recent years have begun gradually shifting away from the traditional teacher-centered model towards adopting the more progressive learner-centered model (Brown K. L., 2003) where emphasis is shifted away from what the teacher is able to teach to learners, to the process of learners constructing and building their own ideas and knowledge. Given the diverse demographics of users of mobile apps (Blok, 2010), and need to appeal to the learning experience of children as outlined in Section 2.2, it would appear that designers can draw many insights from the learner-centered model. By being more cognizant of curriculum design, and the methods used in helping learners build up knowledge (Bednar et al., 1995), app designers can more effectively achieve intended learning outcomes.

2.3.2 Designing for Engagement

Cognitive psychologists, have shown that teaching is most effective when learners are motivated to actively engage in their own learning (Catalano, 1999). The main assumptions of constructivist theories and, by extension, the learner-centered model, are that learners develop the ability to decide how and what they choose to learn, and manage their own learning processes (Fotos & Browne, 2004). However, in many cases teachers have reported that students are unwilling to take on more active roles in their learning process (Brown et al., 2007). It is hence crucial that designers of learning apps account for learner engagement when designing their apps. One possible design paradigm that has been gaining popularity in recent years (Gartner, 2011), is Gamification.

Gamification, is the use of game design characteristics in non-game environments (Deterding S. , 2012). More specifically, Gamification is the integration of game dynamics and mechanics into non-gaming applications such as websites, internal training programs, community building activities, marketing campaigns and customer service, to drive desired behavior. Gamification exploits basic psychological urges such as goal-setting, competition, and the need for status and recognition (Antin, 2011), to bring about significant increases in motivation and engagement. By providing a framework to promote desired behaviors (Lee & Hammer, 2011), Gamification seems to be a viable approach to motivate learners to become actively engaged in their own learning (Muntean, 2011). In fact, many teachers have already begun to bring game mechanics into classroom teaching in order to boost motivation and achievement (Stott, 2013). App designers too, could potentially apply gamification to engender and enable a learner-centered education environment. One of the key tenets of Gamification, is to provide timely and meaningful feedback in response to user actions (Simões et al., 2013). For example, in a game it is common for players to receive rewards and positive feedback for achieving certain goals in the game. Similarly, in gamified apps feedback loops are used to reinforce desired user behaviors (Crowley et al., 2012) and keep users actively engaged with the system. Additionally, many games employ the concept of quests, which are a detailed list of challenges to fulfil in order to attain a specified reward (Navarro et al., 2013). Similarly, gamified apps use quests to provide a sense of adventure, and motivate users to continually explore different aspects of the system (Homan, 2013). The use of these game design constructs along with other game design aesthetics such as animations, graphics and audio feedback, help serve to elicit and retain user attention (Deterding et al., 2011).

In Section 2.1, we looked at the challenges involved in designing for mobile platforms, and the need to organize and present information effectively on limited screen sizes. Given that game designers often look for novel ways in displaying player information (El-Nasr & Smith, 2006), perhaps designers of learning apps could also draw inspiration from game design aesthetics. For example, it is common in game design to use heads-up displays (HUD) for organizing and presenting pertinent information (Rogers S. , 2014). By adopting such an approach, app designers would also be able to place relevant information available at a glance (Mitchell, 2012) without requiring additional steps or navigation by the user, thereby alleviating some the navigational challenges in mobile design. In Section 2.2, we explored the need to appeal to the *Cognitive*, *Psychomotor*, and *Affective* aspects of the child's learning experience. The aforementioned game mechanics, and game design aesthetics from the Gamification approach appear to be able to address these areas. For example, quests provide a sense of structure and allows users to visualize clear paths (Navarro et al., 2013) to take for *Goal Accomplishment*. Game design aesthetics provide the necessary affordances for players to navigate gameplay (Humphreys, 2003). By adopting similar approaches, app designers would be able to create *Awareness* and guide the user along. Graphics and animations augment and react to the users' *Psychomotor* touch response to onscreen elements, and feedback loops create an *Affective* relationship (Miller, 2013) by rewarding positive actions taken.

2.4 Designing Learning Apps for Children

Based on our review of existing literature, we hence surmise that there are 3 major areas that designers need to take into account when designing learning apps for children. The 3 areas are: Design Considerations for Mobile, Design Considerations for Children, and Design Considerations for Education. Figure 2 illustrates a summary of these 3 areas.

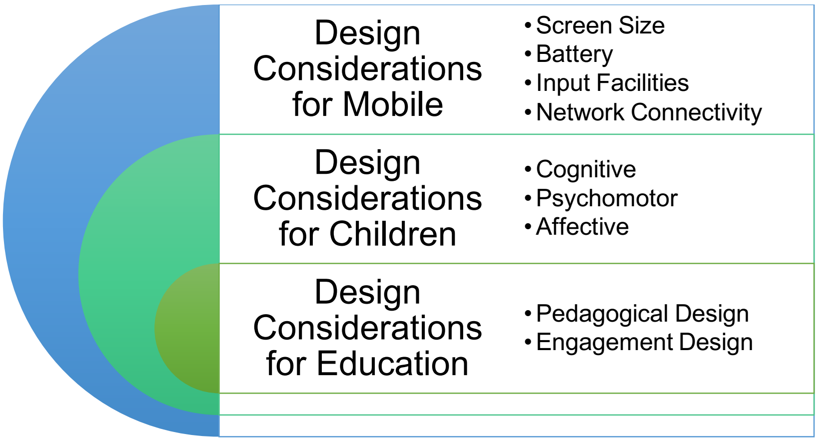

Figure 2 – Design Considerations for Children Learning Apps

In order to design effective learning apps for children, app designers should take into account these 3 areas of consideration. Firstly, they would need to ensure that the apps are designed to work well on mobile, by ensuring that the app does not impact battery life unnecessarily (Huang, 2009), that it is able to handle unstable network conditions (Ioannidis et al., 1991), and that the user interface is optimized for smaller touchscreen based inputs (van der Velde, et al., 2004). Secondly, they would need to design the app in a way that would appeal to the innate psychological tendencies of children (Krathwohl, 2010). Lastly, they would have to ensure that the apps are designed around sound pedagogical practices (Bednar et al., 1995), and in ways that can elicit and retain learner engagement (Catalano, 1999). In the later sections of this paper, we shall analyze how some of these principles have been applied in design of real world children learning applications.

3. Evaluation and Analysis

To better understand the practical implications of the design considerations outlined in our literature review, we shall analyze two case study examples to see the extent to which designers have accounted for the three major areas of consideration. Follow which, we will present a comparison of the two apps and comment on the efficacies of their design.

3.1 Case Study 1: Peekaboo Moona

The first mobile application we examined was *"Peekaboo Moona: Fun First Games"* developed by *Baby & Toddler*. This mobile learning application is essentially a children's learning app designed to allow children to understand words and to cognitively relate the words to a corresponding image of the object. The categories of topics covered include; vegetables, on the farm, professions, and heroes.

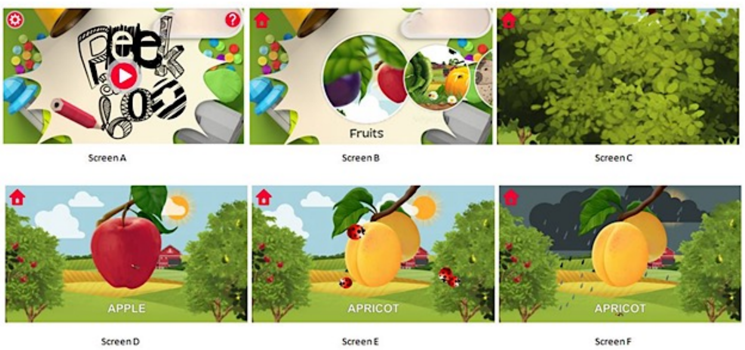

Figure 3 – Screenshots of Peekaboo Moona

In the application, the users are led through different learning environments in the above categories, so that the task of interacting with the objects are accomplished. The user is then returned to the main menu to try other categories.

3.2 Case Study 2: Duolingo

The second mobile application we examined was the mobile app *"Duolingo"* developed by *Duolingo*. The app is designed to cater to both children and adults, and it allows for interested parties to pick up a second language. The app distinguishes itself by the intensive use of gamification techniques its clean design language.

Figure 4 – Screenshots of Duolingo

In this application, users get started on learning a language by following through a series of activity screens that map pictures to words. The user is tasked to identify the words correctly in order to get a badge. This contributes to the incentives in the form game attributes. e.g. XP points and badges.

3.3 Comparison of Design Approaches

A comparison of the utilized design features in both applications is shown below:

Design Considerations for	Mobile	Children	Education
Peekaboo Moona	- User interface is formatted well for touchscreens - Download modules are very large	- Single widget screen optimizes cognition - Insects flying across, Rainy Scene: *Psychomotor* -Trees scene: counter intuitive	- Uses bright colors and sounds - No clear use of any pedagogies - Engagement design is mostly visual only
Duolingo	- Clean interface optimised for mobile - Optimal use of device battery	- Mascot and clean navigation: *Cognitive* - Feedback Loops: *Affective* - Sounds & animations: *Psychomotor*	- Very clear and structured lesson pedagogy - Uses gamification to create engaging experiences

3.3.1 Design Considerations for Mobile

The user interface (UI) for Peekaboo Moona has been optimized for touchscreens, with relatively large touch targets for onscreen navigation. However, the landscape orientation of the UI (Appendix C, Figure 1) suggests that the app has been mostly ergonomically tailored for use on tablets rather than smartphones. Whenever a new module is downloaded, a loading screen with animations and a progress bar is presented (Appendix C, Figure 2) to inform the user of the current status. However, based on our informal testing of the app, most of the modules took significantly long to complete downloading. It would appear that the app designers had not taken into account the network bandwidth limitations of mobile devices. In contrast, Duolingo operates primarily in portrait orientation, suggesting that it has been optimized to target smartphone users. The UI is also minimalistic in nature, with large touch targets and buttons for easy navigation. In our informal testing, the app launched quickly with no signs of any significant lag when launching the lessons. Battery usage reports on our Android based devices also showed that Duolingo consumed less energy when used for the same period of time. This could perhaps be attributed to the heavier use of graphics and animations in the Peekaboo Moona app.

3.3.2 Design Considerations for Children

In Peekaboo Moona, users are presented with one main widget on screen at a time (Appendix C, Screen D). This helps to reduce onscreen clutter, simplifying the *Cognition* needed for a child to navigate and complete the activity. To stimulate the *Psychomotor* aspects, the app introduces insects flying across the fruit (Appendix C, Figure 1- Screen E), and to changes the background to a rainy scene (Appendix C, Figure 1- Screen F) upon clicking in an attempt to entice the child to interact with the screen. *Affective* features of the app include the various sounds and graphics used in order to draw interest from the child. One counter intuitive navigation pattern we discovered, is illustrated in Screen C, where the scene of trees is supposed to lead to the screen with the fruit in Screen D, but this is only possible if the user clicks at the bottom half of the screen and nowhere else. Duolingo takes a slightly different approach. Rather than using the entire screen as a canvas of colorful graphics, it makes use of more subtle cues to draw interest from children. The app presents a mascot owl at certain points to guide uses the *Cognition* of navigating the app. Feedback sounds and animations are used strategically to present *Psychomotor* responses to a user's touch input. The appropriate use of colors against a clear background, allows for clean interface that is easy to navigate. Duolingo also employs the use of Gamification, providing frequent messages of positive re-enforcement (Appendix C, Figure 5 and 6) in order to establish an *Affective* relationship with the learner.

3.3.3 Design Considerations for Education

The use of bright colors and sounds in Peekaboo Moona intrigues children and aids to sustain their attention and interest. (Appendix C, Figure 1- Screen D). However, it appears that there are no other forms of engagement design beyond just the graphics and animations, which could prove to be more of a distraction than help. Furthermore, the lessons simply take place in a linear fashion with no clear adoption of sound pedagogies or instructional strategies. Duolingo on the other hand, has a very clear and structured lesson pedagogy. Appendix C, Figures 4 and 5 shows how the material is designed to test users' understanding of the words through various means, including picture association and word matching. Their lessons are also organized into different categories by interest topics, and they cater to learners of varying skill level backgrounds (Appendix C, Figure 3). Through the use of game mechanics and aesthetics (Appendix C, Figure 6), Duolingo is able to create an engaging environment where there is clear recognition of efforts, and learners feel compelled to learn more.

3.4 Insights Gleaned

Our study of the two applications showed that the designers of both apps had used varying degrees of the design considerations we outlined in the literature review. It can be seen that while both apps were designed to appeal to children, there are several important areas where the design of Duolingo had an edge over Peekaboo Moona. While it is the case that Peekaboo Moona had attempted to address the design considerations for children, they failed to consider the necessary optimizations required to run apps on mobile devices, hence negatively impacting network and battery usage. Furthermore, the lack of pedagogical design and their superficial use of multimedia to draw engagement, brings into question the effectiveness of the app in achieving its' learning objectives.

In contrast, Duolingo through the strategic use of sounds, pictures and animations, also managed to address the design considerations for children, while at the same time being optimized to not place too heavy loads on mobile device resources. The clever use of Gamification techniques and structured lesson pedagogies also serve to go a step further in helping to engage learners to achieve their learning goals. Indeed, informal ratings on third party review websites (Appendix C, Figure 7) show that Duolingo had managed to achieve a rating of 5 stars and Apple's App of the Year award, compared to the 2 stars rating of the Peekaboo Moona app. This suggests that the key limitations as identified in our analysis in Section 3.3 had possibly impacted how users rated the Peekaboo Moona app. The above serves to surmise that a possible relationship exists between successfully implementing the design considerations, and the success of an app, and is worthy of further study.

4. Conclusion and Recommendations

With the rapid proliferation of mobile devices, and the widespread adoption of mobile apps (Perez, 2016), there has been keen interest from both parents and teachers (Olney, Herrington, & Verenikina, 2008) in using mobile devices as tools to support children learning. The popularity of educational apps targeted at children (Carly Shuler, Zachary Levine, Jinny Ree, 2012), has created lucrative opportunities for app designers to innovate in this space. However, there has been a lack of established theoretical frameworks for understanding and analyzing the unique design considerations for designing learning apps targeted for children.

In this paper, we have conducted an extensive review of existing literature to develop a holistic approach for understanding the design considerations required for creating mobile learning applications for children. Through the use of case studies, we then analyzed and exemplified the practical implementations of these design considerations in real world applications. Furthermore, we compared and contrasted the different approaches and postulated reasons for their differing successes. However due to the limited timeframe of this research, we were unable to conduct actual experiments to test and validate our understanding of the design considerations outlined in Section 2.4. Future research may wish to look into this by conducting observational studies on children, as well as testing the design concepts by means of developing actual prototypes.

Appendices

Appendix A – Leaner-Centered Psychological Principles

Cognitive and Metacognitive Factors

1. *Nature of the learning process.* The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience.
2. *Goals of the learning process.* The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge.
3. *Construction of knowledge.* The successful learner can link new information with existing knowledge in meaningful ways.
4. *Strategic thinking.* The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals.
5. *Thinking about thinking.* Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking.
6. *Context of learning.* Learning is influenced by environmental factors, including culture, technology, and instructional practices.

Motivational and Affective Factors

7. *Motivational and emotional influences on learning.* What and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states.
8. *Intrinsic motivation to learn.* The learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests, and providing for personal choice and control.
9. *Effects of motivation on effort.* Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without the learner's motivation to learn, the willingness to exert this effort is unlikely without coercion.

Developmental and Social Factors

10. *Developmental influences on learning.* As individuals develop, there are different opportunities and constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account.
11. *Social influences on learning.* Learning is influenced by social interactions, interpersonal relations, and communication with others.

Individual Differences

12. *Individual differences in learning.* Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity.
13. *Learning and diversity.* Learning is most effective when differences in learners' linguistic, cultural, and social backgrounds are taken into account.
14. *Standards and assessment.* Setting appropriately high and challenging standards and assessing the learner as well as learning progress—including diagnostic, process, and outcome assessment—are integral parts of the learning process.

Adapted from: *Learner-centered psychological principles: A framework for school reform and redesign* (APA, 1997).

Appendix B – Teacher-Centered vs. Learner-Centered Approach

Concept	Teacher-Centered	Learner-Centered
Teaching goals	• Cover the discipline	• Students learning o How to use the discipline o How to integrate the disciplines to solve complex problems o An array of core learning objectives
Organization of the curriculum	• Topics in textbooks	• Cohesive program with systematically created opportunities to synthesize, practice, and develop increasingly complex ideas, skills, and values
How students learn	• Listening • Reading • Independent learning, often to compete for grades	• Students construct knowledge by integrating new learning into what they already know • Learning is viewed as a cognitive and social act
Pedagogy	• Based on delivery of information	• Based on engagement of students
Course delivery	• Lecture • Assignments and exams for summative purposes	• Active learning • Assignments for formative purposes • Collaborative learning • Online, asynchronous, self-directed learning • Problem-based learning
Instructor's role	• Source of knowledge	• Designer of learning environments

Adapted from: *Assessing Academic Programs in Higher Education* (Allen, 2004)

Appendix C – List of Figures for Section 3: <u>Evaluation and Analysis</u>

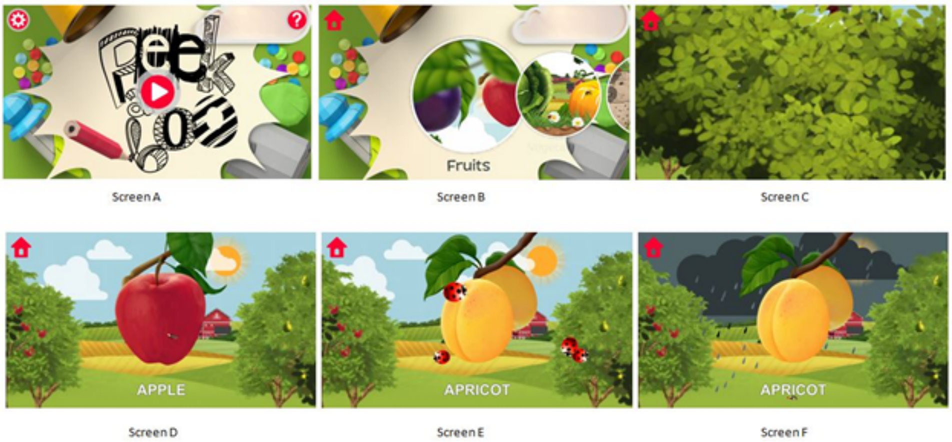

Figure 1: Peekaboo Moona: Application User Interfaces

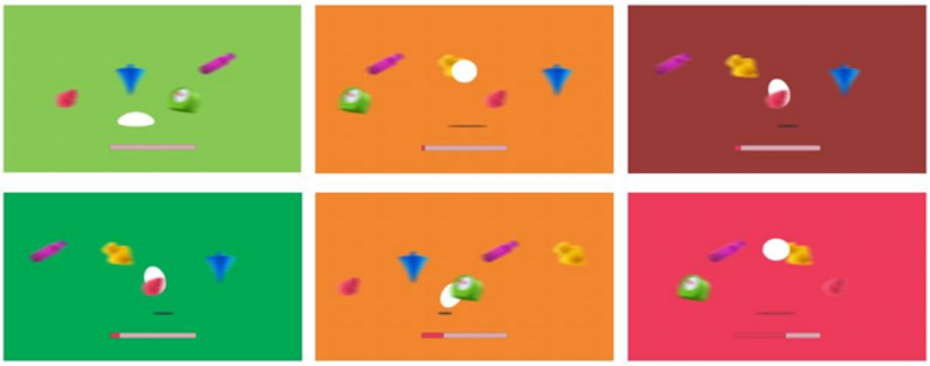

Figure 2: Peekaboo Moona: Module Download

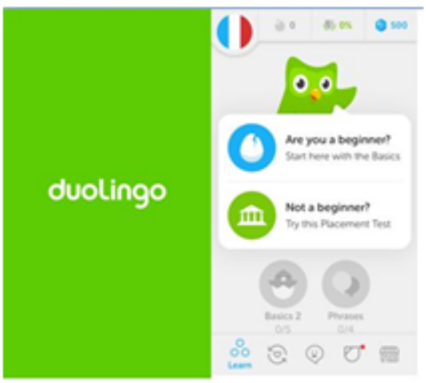

Figure 3: Duolingo Splash Screen and Start up

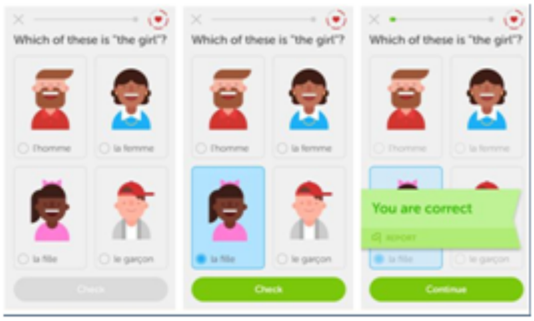

Figure 4: Duolingo Presentation of Learning Content

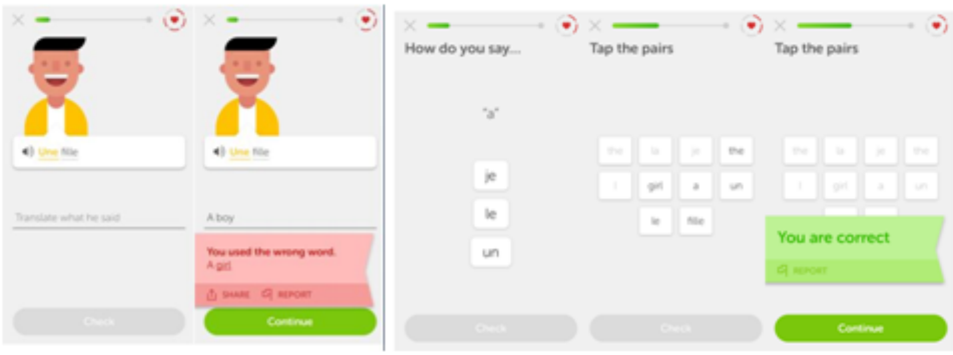

Figure 5: Duolingo Tests on Cognitive Association

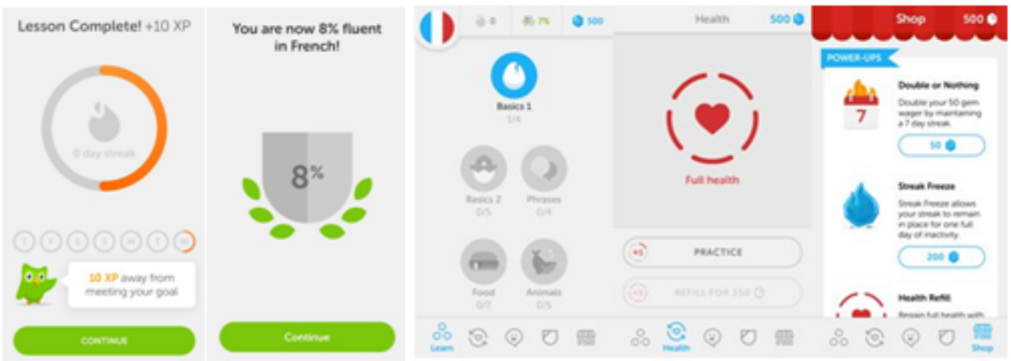

Figure 6: Duolingo Gamification

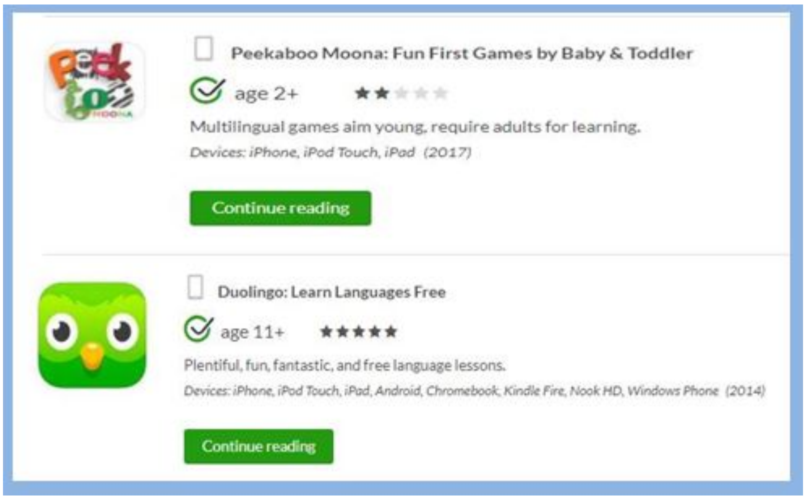

Figure 7: User Ratings (www.commonsensemedia.org)

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