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Mobile Applications: Games that Transform Education

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Abstract:

A breakthrough development in the crossing of education and technology has long been a subject of heated debate. The possibility of combining machine learning and attention-grabbing graphics to not only make learning easy and interesting, but personalized, was the original impetus for gamifying education.

In this paper I investigate the history of technology and media through the lens of education, and attempt to apply the principles, practices, and insights gleaned there within to an educational mobile game. Specifically, the mobile app I designed for the iPhone and Android operating systems focuses on teaching players SAT I math concepts using Nintendo's wildly popular *Pokemon* game design model.

I. Introduction:

When *Sesame Street* first came out in the late 60's, people didn't believe that you could teach through a non-traditional medium like television. They said that the experience couldn't be tailored well enough; that television was the *opposite* of education – a mind numbing activity made by the people in Hollywood. But, the advantages and possibility that existed in what could come of a successful educational television show were too great. The reach was the foremost boon – the capacity to suddenly teach children in every household with a television in America at the flip of a switch. Ultimately as we know, *Sesame Street* became a paradigm-shifting foray that changed education forever; so much so that even today, over 40 years since *Sesame Street* first aired, it's still one of the most successful and impactful shows ever aired.

There are many parallels to be drawn from the era of *Sesame Street* and today. The late 60's and 70's were a period of tremendous innovation and technological development – and many areas of study just couldn't keep up with developments in the world. Education today is much the same as it was in the 60's and 70's – stagnant despite leaps and bounds in innovation in everything from personal computers to energy. Beyond these advances, however, I believe, is the advent of mobile smartphone technology.

As elaborated on later, the widespread penetration of smartphones globally offers tremendous opportunity and synergy with classical understanding of education. In addition, in today's world we know what addicts people to technology; what makes them check smartphones ten times during dinner. In 2011 *Angry Birds* was the first software application of any kind to reach 1 billion downloads. (Heriksen, 2012) *Angry Birds* reached a billion devices. By comparison, the total number of televisions in American homes in 1960 numbered just 52 million. (Lefky, 2007)

In light of the current state of education and technology, my thesis revolves around an attempt to develop a mainstream, high-graphical-quality mobile game that tries to teach SAT I Math using the state-of-the-art knowledge in educational psychology and game theory.

II. The Problem: *Inefficient Teaching*

The current paradigm of learning is broken in the sense that much of the way we're educated and taught has stayed stagnant for decades. And, more importantly, the technology and techniques exist in our modern world to rectify this fact.

For example, textbooks present material in an elaborated form such that the information important to retain is often obscured by extraneous language and formalism. Part of the reason for this is that textbook authors are motivated to give credit to contributing members of the field. More often though, textbook authors go into unnecessary depth discussing the experiments used to arrive at a conclusion. In today's world, however, knowing an appropriate level of abstraction is essential. Indeed, rather than looking up questions in textbooks, students often defer to the Internet for a quick summary of an answer. The extraordinary success of Khan Academy exemplifies this fact. And yet, Googling almost any topic results in a scattered and inefficient presentation of material. The point here is that there is no centralized location for independently learning information in an integrated, and interesting, context.

School is a forced learning environment that frequently presents material in a passive and uninteresting lecture format. As such, students have to pay an inordinate amount of attention to learn from class. In fact, almost all types of learners suffer from this situation because it is just not efficient. More specifically, Visual-Spatial learners often never get to interact with the material in a visual manner that goes beyond a few diagrams in a PowerPoint. Auditory learners, while being able to attend to lectures, usually don't get the chance to explain the concepts they seek to retain to other people. Yet, communicating these is a fundamental method by which people organize and consolidate their understanding of a topic. Similarly, Kinesthetic learners rarely get to interact in a physical manner with the material. Lab classes, for example, aim to use this approach, but are frequently limited in their impact due to a lack of resources and sufficient time.

In essence, I believe not only that current educational techniques are very inefficient for the number of reasons listed above, but also that recent development in technology are far from reaching what potentially could be. This is especially true in mobile – many facets of interaction unique to the mobile, smartphone platform lend incredibly well to education and should be applied.

III. What's Been Done: *Related Works*

Because my project is very cross-sectional in nature, there are three separate areas of related works that need to be addressed; namely, the history of educational games, mobile games, and educational media. The most successful products and software in these three categories each offer tremendously valuable lessons and insights I've tried to apply to my thesis.

III.1) The History of Educational Gaming

The history of educational gaming can generally be broken down into two separate areas of interest. First, is the conception of educational gaming and further justification of why the gaming paradigm lends particularly strong synergy with classical approaches to the way people learn. Second, is the study of what's known about good educational game design – in essence, what works well and with whom.

III.1.1) Conception and Justification

The idea of utilizing game design and game theory to teach players academic subjects is by no means something new. As far back as 1955, Huizinga argued in his work *Homo Ludens* that human activities that fall into the play category – of which games are one of the most important modern subset of – are some of the most important. (Huizinga) This theory formed the basis for what Csikszentmihalyi's postulated in 1975 – the psychology of *flow* – a mental state in which a person is fully immersed in a balance of challenge, skill, control, and satisfaction that so takes up the complete attention of said person that all other sensory and cognitive distractions fall by the wayside. This concept of *flow*, as Csikszentmihalyi puts it, is most typically experienced in play, and games are the most prevalent form of play. Now, the state of *flow* is of such value because it is, fundamentally, completely focused motivation – single-minded immersion that is perhaps the pinnacle of performing and learning. (Csikszentmihalyi, 1975) This is one of the primary justifications for educational gaming; if *flow* can be achieved, the ultimate state of pushing one's mental faculties to the limit and learning comes about – and the most prevalent and significant way of achieving *flow* is through games.

III.1.2) Educational Game Design

In the decades following the establishment of the original psychological basis for education gaming, many studies looked not only at valuable subjects such as the genres of learners and how game design can be applied to these varied behaviors, but also the different game play activity modes and how these can be best applied based on individual preferences.

A landmark study by Junjie in 2008 provided the basis for differentiation in learning behavior not in accordance with classically known educational psychology, but rather specifically in the paradigm of education and gaming. (S. Junjie, 2008) In his study, the genres of learner's game behavior was divided into six categories: creative learners, exploring learners, collaborate learners, trial and error learners, inquiring learners, and entertaining learners. Each of these different types of learners require that specific design strategies be used so that regardless of learning type, all students remain engaged. Creative learners need an environment that allows for a diverse set of solutions, whereas exploring learners need the game to lead them freely. Collaborative learners need effective interaction and communication, trial and error learners need a large base of support and help, inquiring learners need the ability to discuss and play different roles, and entertaining learners need choices, challenges, and an engaging story. These various types of needs provide the basis for good game design – taking into account the differentiation in player preferences in vital for creating educational games that have widespread appeal and efficacy.

Junjie's study was built upon by Joseph and Kinzie in 2005 when they divided types of gameplay into six corresponding categories that mirrored some of Junjie's chosen areas, and looked at play preferences among test subjects. The categories of play their study focused were: active play, explorative play, problem-solving play, strategic play, social play, and creative play. Active play was characterized as involving intensely performative input that involved response time and combination input. Explorative play, on the other hand, is where physical travel is simulated so that the player is allowed to discover new areas and challenges. Problem-solving play and strategic play have the same basis of interaction under Junjie's paradigm, but problem-solving focuses more on short-term puzzles and challenges, whereas strategic play focuses more on long-term resource management. Social play focuses on the interactions and collaborations between characters, and, lastly, creative play focuses on the ability to create and interact with elements during the game.

Now, the interesting takeaway from Joseph and Kinzie's study lies in their experiment on children's preferences between the different types of gameplay. Because, while ideally, games would like to encapsulate all six types of interaction so as to interest as many relevant parties as possible, often times games have difficulty creating a successful paradigm in even one of the six genres. The results of Joseph and Kinzie's regression shows that the most ideal form of play, by nearly a factor of two, is explorative play. Hence, an important part of my implementation, elaborated on further in section IV, is centered around explorative play. However, it's important to note here that the authors also gave breakdowns of preferences between the two genders. Boys actually preferred active play most by a fair margin, but active play was least preferential for girls – tied for last with strategic play. Boys preferred explorative play second best, and girls preferred explorative play most – the reason why explorative play is,

on average, the most preferred genre of gaming. For reference purposes, the top three types of play for boys were active, explorative, and strategic, the top three for girls were explorative, creative, and problem solving, the bottom three for boys were creative, social, and problem solving, and the bottom three for girls were strategic, active, and social. (Mable Kinzie, 2008)

III.2) Mobile Games

While a relatively new market, mobile games, specifically those on the Apple App Store for the various iterations of the iPhone, and those on the Google Play store for any smartphones running an Android operating system, have expanded rapidly since the groundbreaking release of the original iPhone in 2007. Unsurprisingly, the mobile game market has grown on average nearly 33% annually since then, and generated over \$9 billion in revenue in 2012. (Nouch, 2013) Hence the reach and impact of mobile games is huge – roughly 129.4 million people in the U.S own smartphones; approximately a 55% mobile market penetration. (comScore Reports January 2013 U.S. Smartphone Subscriber Market Share, 2013)

The most successful games of all time in this market not only generate hundreds of millions in revenue annually, but, most importantly for my thesis, have a specific paradigm of interaction with users. Games like *Angry Birds* (#1), *Fruit Ninja* (#2), *Doodle Jump* (#3), *Cut the Rope* (#4), and *Words with Friends* (#5), aren't the "hardcore" games that consoles platforms like the Playstation 3, Xbox 360, or Nintendo Wii have stereotypically produced, but rather are targeted towards those 10 minute train rides in-between errands, or the small intervals people spend in waiting rooms unoccupied; really any instance of time when users' attentions aren't already entertained. (iTunes Store Top 10 Apps - Games)

Thus, the first main point to learn from the paradigm of mobile games is that users aren't planning time and sitting down for 1 to 3 hour intervals of play once or twice a day, but rather 5 to 15 minute intervals six to ten times a day. In constructing my thesis, this was the first point that made mobile make so much sense – classical theory in education and learning is rooted in practice, practice, practice across days or weeks to really internalize concepts. It's why cramming, a more-than-popular practice in today's schools and universities, doesn't work; even if trying to learn a semester's worth of class information can get you through the exam, nothing sticks for any extended period of time. (Allen-West, 2007) Hence, the mobile user interaction paradigm naturally champions one of the holy grails of educational psychology – how to get students or users to practice for brief periods of time spread out across days or weeks or months; a type of practice that reinforces and internalizes educational concepts for the long run.

The second main point to learn from top games like *Angry Birds*, *Fruit Ninja*, and *Cut the Rope* is a study in uniqueness – what is it that's particularly special about these apps that truly made them viral? After all, almost all of the top-grossing mobile games came out of small to truly miniscule studios dotted across the country – ironically, truly establishes franchises with

lauded history and sales, like Square Enix's *Final Fantasy* or Sid Meier's *Civilization* haven't had any groundbreaking success in the mobile market. And, it's not as if the game concepts behind the top-selling mobile games is really unique – for example, *Angry Birds* is in essence just a simple catapult game not unlike those that have been in circulation over the past 15 or even 20 years since the advent of flash-based games. The uniqueness really lies in the visual experience – the character design and user interface design create such an iconic, sticky experience that's not only hard to forget, but hard to replicate. (Mauro, 2011) It's this facet, centered around clean, easy-to-digest, cutesy and visually appealing design that's really permeated all of the landmark mobile games – and is a lesson I've tried to apply to my thesis.

III.3) Educational Technology and Media

The topic of educational technology and media is a wide-ranging area of study that encapsulates everything from Mattel's \$3.6 billion loss in acquisition of *The Learning Company*, one of the most disastrous buyouts of all time, to *Future U*, a relatively unheard-of but nevertheless stereotypical failure by Kaplan to enter the Nintendo DS gaming space in 2008. (Cave, 2000) However, in a landscape dominated by badly timed launches and failed ventures, two television shows, one developed in the late 60's and the other broadcast in the mid 90's, truly established the impact and efficacy that educational technology and media had the potential to be.

The first barely got off the ground because the concept and vision were so foreign for its time, and yet it's still airing today, over 40 years later – PBS's classic kids show *Sesame Street*. Now, the history and development of *Sesame Street* is an incredibly interesting and in-depth study in how truly cutting-edge experts in as disparate fields as education, media, psychology, and history came together to try and do something no one thought could work or had made work ever before. However, what came of it, the uniqueness there within, and what can be learned from that, is where I'd like to focus.

Sesame Street was built on one simple principle: if you can hold the attention of children, you can educate them. But, how can you hold their attention? Well-accepted theory at the time postulated that we are stimulated by whizzes and bangs and bright flashes on the screen, but the psychologists on *Sesame Street* called foul. This was the main point I took away from *Sesame Street* – attention, at least for children, isn't lost based on interest as we would classically believe, but is lost based on understanding. In all of the pre-launch studies *Sesame Street* undertook, kid's looked away when the story was too complex or confusing, not when there were less or more whizzes and bangs.

Secondly, *Sesame Street* has really stood the test of time because it's one of the only forms of any media or technology with an educational bend that time and time again has proven efficacy. Kids who watched the show consistently performed significantly higher on tests in learning not only 6 weeks after they'd begun watching the show, but also another 6

weeks after they'd stopped watching the show. The main takeaway here, is that testing efficacy in education is a staple – and is definitively in the next steps for my thesis.

Sesame Street was also famous because of their invention and use of the “the distractor test”. Basically, before airing any individual episode, the directors would test run the show in front of groups of children with the episode running on one television and random slides that shifted every 7 seconds running on another television next to *Sesame Street*. If the children weren't watching the episode at least 50% of the time, the episode would be cut and reworked. On average, aired episodes of *Sesame Street* had an 80% attention rate by the distractor test. Now, the second groundbreaking product in educational technology and media was so groundbreaking because of this very test. *Sesame Street* was lauded as so revolutionary because of how “sticky” or memorable, it's episodes were due to the distractor test filter. One show, however, is even more “sticky” and effective than *Sesame Street* – Nickelodeon's mid-90's classic *Blue's Clues*.

Sesame Street, for all its success and impact, had two fundamental disconnects in assumption and direction. First, *Sesame Street* assumed that kids didn't have the attention span to follow a single story for 30 minutes, and hence episodes were more like a magazine than a short story; composed of short, back-to-back vignettes rather than a continuous plot. Secondly, *Sesame Street* was meant to be a show that parents and kids could watch, enjoyable, together. Hence, some of the concepts, story points, references and word play in *Sesame Street* were far beyond the capacity of a child to understand.

Blue's Clues handily rectified both of these points. The show was defined by 30 minute continuous stories, a flat, 2-dimensional feel, a slow deliberate pace, script punctuated with long pauses, no upper-level humor or word play, a reliance on repetition and interaction with the audience, and a relative lack of creativity in character creation. Basically, a half-dozen factors that made adults and teenagers cringe at the prospect of sitting through an entire episode. However, *Blue's Clues*, by every metric, is stickier and even more effective than *Sesame Street* in problem solving and flexible thinking! The takeaway here, confirmed by new research, is that learning from a young age on, is centered around storytelling – and that's the lesson I've tried to apply to my project. If story, and hence psychological attachment can be really established alongside learning, it not only exponentially increases metrics like attention, time spent, repetition of use, but also, most importantly, efficacy. (Gladwell, 2000)

IV. Project Solution: Addictive Learning

The software solution I've designed is created to target and implement all of these points – mobile as an ideal paradigm of interaction for learning, clean and iconic design as the cornerstone of success in mobile gaming, the importance of testing for efficacy, and storytelling as a staple for memorability and engagement.

In essence, my thesis is an educational mobile game developed with an eye on Nintendo's *Pokemon* franchise. The educational aspects focus on the SAT I exam's math section as a jumping off point. I chose this test not only because of extensive personal experience with the SATs, as well as demonstrated success, but also because they allow students across the nation to demonstrate their learning in a standardized format to colleges. My thesis is a full-immersion educational environment for these exams. It's an educational role-playing game that utilizes advances in technology and research in neuroscience to increase learning efficiency and "stickiness," or how memorable a lesson is.

IV.a) Software Design and Implementation

In designing, animating, and coding the game, there existed many options and choices ranging from Objective C in X-Code for the Apple platforms and Java for Android, to more high-level software development kits or game engines like Unity or Cocos 2D. Given the design and implementation-nature of my thesis, I in essence needed to keep in mind a few caveats: I needed reliable audio, simple and efficient transitions between interaction screens, and, most importantly, 2D sprite animation.

With these caveats, I decided to develop in the Corona SDK, which uses the Lua scripting language. Corona comes built-in with screen transitions and movement, as well as a roundabout method for object-oriented design in Lua. Lastly, and arguably most importantly, Corona has a built-in system for sprite animation using sprite sheets that allows for the creation, implementation, and usage of simple 2D character expressions and 2D attack animations.

In terms of the overarching design of the actual software, my thesis is set up so there are several different screen states: the home screen, conquering unlocked castles (Conquer), exploring the world (Adventure), battles, and cut scenes. These are pictured below in diagrams 1 through 6:



Diagram 1 – Home Screen: The home screen of my thesis, depicting the conquer screen, adventure screen, and world screen. On any screen it's also possible to check-on or update your monsters.



Diagram 2 – Monster Screen: The pull-down monster check screen. Here, you can level up your monsters using experience gained through combat, which is depicted in the lower left of the screen. The lower right of the screen shows available money.



Diagram 3 – Adventure Screen: This is the adventure screen, where players can navigate through the route to unlock gyms by tapping on the icon with the highlighted blue circle. Each bush, tree, or trainer results in a battle.

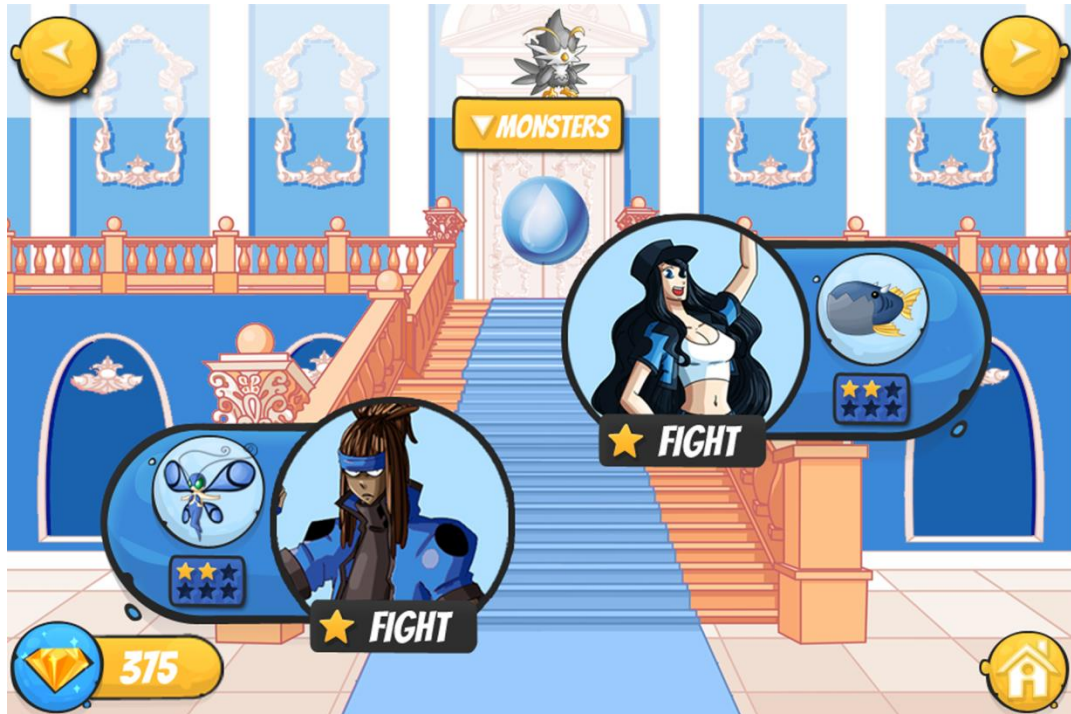


Diagram 4 – Conquer Screen: This is the unlocked conquer screen, where players can navigate through different trainers and enemies to earn trophies.



Diagram 5 – Cut Scene: This is an example of one of the cut scenes in the game, where players are learning about plot.



Diagram 6 – Battle Screen: This is an example of a screen mid-battle. The battle system is elaborated on further in the section IV.d) Educational Psychology.

Each of these screen states is a separate Lua file, and the Corona SDK navigates through currently-loaded screen states based on player input. For example, home, conquer, adventure, and the introduction cut-scene are all separate Lua files.

In addition, each separate monster has its own Lua file, set up so that those monsters can be referenced as objects in the screen navigation files. Each monster holds methods for all relevant stats and moves, as well as creation functions and set functions for those respective stats and moves.

Lastly, it's worth mentioning the file storage system in place. The file storage system comes into play for two different situations. The first is storing player and game progress from different iterations of play. I decided to use JSON files to store any save info, because JSON file methods can be imported quickly, easily, and efficiently into Corona. In addition, JSON files are easily stored and read as array objects, with each array index defined by a declared variable name instead of a number.

Secondly, the game dynamics also require that a fair amount of static information be easily searchable. Such game dynamics include – referencing monster sprite animations, finding the correct move icon location using a text database, question banks for the combat system (elaborated on later), as well as references for different move statistics. To find the correct values for these, there exist several static text files among the game files that can be easily opened and searched line-by-line. Lastly, these game files, because of the way the iPhone and Android systems references documents, need to be moved into the documents directory of the smartphone in order to be used as reference databases.

IV.b) Target Audience

Because of the educational bend of the project towards SAT I Math, as well as the overarching design of the game, my thesis has a three-fold audience. The first, and most obvious, are students themselves. Students who are motivated to study for the SATs, but can't manage to sit down and really grind through books, are the main target audience. The second target audience is parents. Parents who want their kids to learn, but can't seem to force them to sit down and get to the books. Lastly, would be school districts – a very difficult audience to appeal to, especially with a game, but ultimately the most rewarding and interesting audience to cultivate.

It's good to keep in mind that, in choosing a specific topic like the SATs of paramount importance in college admissions and, consequently, the future of students, a certain grade of motivation is present to really score well. This concept applies across all three audiences, and is really what I believe will be most compelling. One of the biggest problems in game theory and psychological approaches to large goals like the SATs and college is that students can't see incremental gains from effort. It's hard to see progress build up and even more difficult to

maintain a steadfast devotion and interest in an achievement or goal that seems so far away. And that really is where my thesis comes into play strongly – it’s easy to see incremental increases, failure isn’t met with complete rejection while winning is compensated accordingly, and along the way users learn slowly and repetitively, arithmetic, algebra, geometry, and statistics.

IV.c) Game Dynamics

The application I’ve developed is a monster-collection-based role-playing-game reminiscent of Nintendo’s *Pokemon* franchise that I grew up with. The game is set-up so that all of the parts of *Pokemon* that made it such a successful, revolutionary, and addicting game have been kept – the aspects of monster evolution, choosing your own personalized starter, a massive world to explore populated by a variety of monsters, the ability to capture and obtain enemy monsters, different elemental affiliations between monsters, and a strength/weakness combat system. See diagrams 3, 4, 7, and 8.

I felt that the universal weakest point in the monster-type role-playing-game franchises was the boring combat system. The reward system in the games is very very strong, based not only on incremental level-ups, but evolutionary changes, different attack acquisition, and defeating various captains/bosses at different points in the game. However, the combat system and experience system, that involved running through areas of the game map encountering random enemies and often defeating tens, or even hundreds of enemy monsters with a simple click-and-attack-to-defeat setup, came across as relatively weak. This is the part of the gameplay where I’ve integrated SAT I Math. SAT I Math has 4 different sections – arithmetic, algebra, geometry, and statistical analysis.

The questions themselves appear relative-closely to how they appear on the SAT I, except with cartoon-stylized graphics and a timer countdown. Based on the speed of answer and the correctness of the answer, the resultant attack is “powerful” or “weak”. I felt that this was an ideal place to implement the educational aspects of the game because SAT I Math prep is so heavily repetition-based anyway. Now, the motivation to repeatedly use an attack isn’t to appease parents but rather to level-up your monsters. And, the reward is much higher for both getting questions correct, and for speed in answering.

To insure that players remain motivated to play, there are several different aspects of the game in place. The first is difficulty scaling – large amounts of research in gamification shows that players have the capacity to repeat about 10 to 20 tasks in a row before being frustrated or bored, and that the ideal success rate for players is between 25% and 75%. Above 75% is too easy, and below 25% is too hard. (Zichermann, 2011) The game scales both the difficulty and the rewards so that players are accomplishing small, incremental goals every step of the way – and learning while they do it.

Another one of the most important and psychologically motivating of aspects in game design is the customization of the experience. My thesis accomplishes this through a

combination of factors – a choice of four different starters at the beginning of play, choice between move acquisition when leveling-up, a capture system to customize the team of monsters being played with, as well as a variety of different encounterable creatures throughout play. In addition the game includes a randomized stats monster creation system. This means that, at conception, each monster is unique in stats and ability to a degree of one in 100,000. Lastly, as players progress through the game, the monsters they choose grow in response to effort applied within the game, evolve, and, in every sense, really become personalized.



Diagram 7 – Character Evolutions: *This is an example of one character evolution. By gaining experience and defeating enemies, Pakipool evolves into Phansoon, which in turn evolves into Aquanesha as the player raises the monster.*



Diagram 8 – Starting Characters: *At the beginning of the game, players are offered a choice between four different characters. This allows customization of their play, and a much higher degree of psychological attachment to the game.*



Diagram 9 – Sprite Animations: *This is an example of one character sprite animation. The six screens of the character play in a row to make it seem as if the character is moving when the animation is called.*

Now, previously was mentioned the importance of iconic, unique, clean, and appealing design as critical to the success of any mobile gaming venture. I believe that on that level, the overall character, graphical user interface, and art design of my thesis is of a level that's competitive on the open market. In addition, my thesis includes a range of sprite and attack animations, that add flavor and action to the 2D game. An example of a six-frame sprite animation can be seen in diagram 9 above.

Lastly, are the story elements of the game that really promote attachment and repeated play. Illustrated and told through cut scenes like the one in diagram 5, the player sets out to conquer all the castles in the land by exploring different areas of the game. These role-playing aspects, combined with the highly differential and customizable parts of the game, as well as the growth, evolution, and capture systems, lend strongly to the psychological attachment of the player to my thesis.

IV.d) Educational Psychology

The educational overlay found within the game is really where learning, meaning, and impact are found. The central element where education has been applied is the combat system. The combat system is setup so that two monsters, yours and an enemy, trade attacks until one of them runs out of health. Each monster has a maximum of four attacks, and each monster is affiliated with an element. In the game there are four elements, fire, water, air, and earth, which have a weakness-strength balance. For example, water attacks deal extra damage to fire, fire defeats air, air defeats earth, and earth defeats water. Now, each of the elements is affiliated with a specific type of SAT I math. As previously mentioned, SAT I math is split into four different subject areas: arithmetic, algebra, geometry, and statistics. Air is affiliated with arithmetic, water with algebra, earth with geometry, and fire with statistics. What this consequently means is that when trying to launch an air-affiliated attack, as seen in diagram 10, players have to answer an arithmetic based question. Now, for each area of math, questions have been sorted into three difficulties – easy, medium, and hard. Which pool is drawn from when attempting to execute an attack is determined by the combo count and the strength of the attack. The combo count is the number of questions gotten correct in a row, and serves as a multiplier for attack strength. However, with a higher combo count, question difficulty begins to rise in order to compensate for continued high power attacks. Also, stronger attacks mean more difficult questions. Lastly, question correctness determines the most significant multiplier

on attacks – if the question is answered correctly the attack is executed normally, if not the attack strength is cut by half and the combo count is reset to zero.



Diagram 10 – Combat System: These four screens show the progression of the combat system from executing one move to finish.

V. Credits and Other Acknowledgements:

At this point, it's important to acknowledge outside input on the development of my thesis. First and foremost, while character animations, stats, move growth, and learning algorithms are all conceived by me, character design was not. Character design for the monsters and their evolutions is owed to Alexander Tansley. Each character was commissioned and Alex was compensated for their use in the game. Secondly, much of the vector graphics, including backgrounds, used in the game are from VectorStock Media. All of the vectors in the game are used under a standard license allowing for royalty free use in design.

Thirdly, the graphical user interface was designed off of a Design Shock bundle of base GUI elements under a license allowing for free use.

Fourth, some of the sprite sheets used for attack animations owe attribution to Pow Studios. All of these animations are free-to-use.

Fifth, music and sound effects were used from SoundBible.com and SoundDogs.com under free-to-use licenses.

Lastly, and most importantly, I'd like to acknowledge Lorie Loeb, my thesis advisor and mentor during the duration of this project, and the incalculable support, advice, and insight she offered throughout the development process.

VI. Moving Forward: *In an Ideal World*

In an ideal world with unlimited resources and time, there are several areas of my thesis in which I'd really like to expand on.

First is really expanding each of the areas of the game that have been implemented. For example, the castle conquest portion of the game can't be unlocked, multiple-monster combat hasn't been implemented, and I would've really liked to have created an interactive tutorial to lead players through the game.

Second is seamless cross-platform movement. One of the most interesting directions that a mobile or tablet-based application opens up is integration across spaces. In essence, the idea that a user can stay attached or within reach of a software platform anywhere they happen to be. For example, users that can move seamlessly from a home computer platform, to a phone on the go, to a tablet upon arriving at school.

Third is the implementation of a social aspect of the game. The inherently one-on-one competitive nature of the battle system naturally lends itself to such combat, and gaming research has found that there is almost nothing more motivating than playing against and with not only your friends, but with other people. Once reaching an appropriate level/experience-cap, players will unlock the ability to fight against other players on global scoreboards, challenge their friends, and challenge large bosses in team-based battles for unique enemy acquisition. I think that the interplay of respect and position combined with the demonstration of academic merit inherent in the gameplay creates a very powerful cocktail of motivation.

Lastly, is big data error targeting. I want to use the incredible amount of data points from the game – of what questions players got right, in how long, at what difficulty level, and even their preferences for different areas of math, to better help them progress. For example, if a player seems to have a habit of missing one type of question, the database can be used to target what other questions players with similar question-answer profiles have missed. In this way, the advantages of having a large data system actually allows the targeting of what areas of math players will have difficulty on before they've even touched those subjects. This not only creates a customized learning experience, but provides what I believe would be an incredibly effective way to learn.

VII. Conclusion: *Why Now?*

Since airing, *Sesame Street* has been looked at by dozens of studies and they all come to the same conclusion: there is widespread educational impact from children viewing the show. In this manner, *Sesame Street* changed an entire generation.

Today the reach and impact of technology has been expanding at an incredibly rapid pace—so fast, in fact, that few fields can keep up with the strides being made. My wish is to not only provide educational opportunity to others, but to fundamentally make learning more interesting and engaging through the use of technology. Ultimately, I want my product to do exactly what *Sesame Street* did—change the way people think about education.

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