MathMaze: An adaptive math game for K-2 students through iPhone applications

1. Concept Overview:

Our project is about the development of an iPhone game named MathMaze. This application is targeted for students in the K to grade two level. The mathematical challenges will vary according to student responses to prior questions. We currently have a working prototype of one level of Math Maze. The mathematical models we emphasize in this version are single and double digit addition and subtraction. We are awaiting funding in order to move to the next phases of implementation, including (1) user testing via iBeta testers, (2) focus groups with mathematics educators, (3) potential redesign, (4) development of more content modules to support student learning of math concepts, and (5) web database improvement.

2. Educational Value Proposition and Impact:

Based on the findings of our preliminary research (see next section) and Klopfer’s (2008) mobile game design principles, we outlined a prototype for an adaptive iPhone math game for PreK-5 students. According to Klopfer (2008), while the function of physical control involves children’s kinesthetic development, requiring players to use physical movement to control the movement of objects within the game, the function of assessment is an indispensable consideration for educational games, since it can help to generate a learning record upon completion of game which can be further examined and reflected on by students, parents, and educators. While the spatial reasoning function helps players to distinguish and decide routes within game, the synchronous playing function gives players an opportunity for collaboration during game playing. Thus, MathMaze is featured with five key principles of a mobile game supporting students' 21st-century skills: 1) navigating information, 2) engaging in sustained reasoning, 3) managing complexity, 4) collaboration, and 5) planning for the unexpected. Furthermore, its adaptiveness feature provides differentiated learning opportunities in classroom, enables students have access to certain type of game content appropriate for their learning levels, and assists teachers in their instruction based on its adaptive evaluation records of individual students.

Our evaluation of Math Maze will focus on assessing the potential utilization of educational mobile application in and out of school contexts by students, teachers, and parents/families. The educational impact of MathMaze will be measured through a pilot study conducted by a team of graduate student researchers at Teachers College at various public schools affiliated with Teachers College. Specifically, the researchers will examine the following: (1) Student interactions with Math Maze: Database server logs recording processes of students' mathematical choices will be collected. Informal conversation-based interviews with children, teachers, and families will be recorded to understand students' interactions with Math Maze: How do students take up Math Maze in and out of school? (2) Teacher utilization of Math Maze as part of their instruction: Focus-group interviews, classroom observations, as well as curricular documents will be collected for investigating teachers' utilization of Math Maze as a cool for assisting instruction: How do teachers take up Math Maze in their classroom teaching? (3) Parent use of data reports provided via Math Maze: Parent surveys and informal conversation-based interviews will be conducted with parents to investigate: How do parents perceive the impacts of Math
Maze? (4) Student improvement on Match Maze: Assessment data regarding students' improvement on mathematical knowledge within the game database will be collected before, during, and at the end of the pilot study, in order to identify the degree of students' improvement.

Collected data and results of data analysis will be shared with teachers, parents, and students to further improve the next-stage development of the design of game mechanisms and content of Math Maze.

3. Research:

In the subject of mathematics, teachers for young children are confused and anxious about teaching and learning in this subject and hesitant to change (Lee & Ginsburg, 2007a, 2007b). There is a huge gap between new recommendations based on research and the current state of classroom practices (Ginsburg et al., 2006). The most pressing need in mathematics education for young children is to improve teacher preparation and ongoing professional development:

“Teaching is an extraordinarily complex enterprise that has much to do with mind, emotions, and motivation-reading. The richness of the kinds of knowledge needed to teach is impressive. As a miniscule sampling, consider this: In order to teach, one needs to know when knowledge, beliefs, skills, etc. are missing, incomplete, or distorted, as well as how people learn. One also knows about others’ emotions and motivation”. (Strauss, Ziv, & Stein, 2002, p. 1476).

Unfortunately, researchers still know little about what actually happens when teachers teach mathematics to young children (Ginsburg et al., 2006). Furthermore, there are common misconceptions held by teachers regarding the teaching of mathematics, including that the use of electronic devices (e.g., computers) are inappropriate for early childhood classroom (Ginsburg, Lee, & Boyd, 2008; Lee & Ginsburg, 2009).

The literature underscores an increased trend in using games as a pedagogically rich and highly motivating educational tool (e.g., Gee, 2003). However, though the market of mobile games is the fastest growing gaming sector in the world (Klopfer, 2008), it is difficult to find research that investigates the primary learning functions (i.e., learning goals/skills behind game playing) and playing mechanisms (i.e., procedures/requirements of game playing) of the current educational mobile games, especially in the subject of mathematics.

To understand the state of content, pedagogy, and design of the current mobile-based games specifically in the subject of mathematics, we did a background study before our development. We first selected a relevant data set of 103 iPhone games in the subject of mathematics from the Apple iTunes Store. These games were chosen through three steps. First, a search was conducted through the iTunes Store using the keyword “education”. Second, a power search was conducted (with the “applications” tab selected) using the keyword “math”. Third, a content analysis was made to examine whether those applications are games or not. Finally, 103 relevant math games were selected from a total of 400 total results. The final data set excluded non-mathematical applications/games and purely functional applications such as calculators.
According to Klopfer (2008)’s guiding categories, we compared the statistical results generated from each category in an attempt to understand the general functions and mechanisms within them. As shown by Table 1, the top three features of the math games are adaptiveness, decision-making, and drill, accounting for 75%, 71%, and 59% respectively among all the iPhone math games investigated. Neither of the functions of synchronous playing and physical control is applied to the iPhone games explored. Meanwhile, the percentages for the functions of assessment and spatial reasoning are 35% and 25% respectively. The background research investigation indicate that there is no iPhone application in mathematics with the function of physical control. In addition, the assessment, spatial reasoning, and synchronous playing elements are missing in most of the applications explored. Over half of the applications (including games) explored are drill-based.

Table 1 Features of Mathematics-related iPhone Games (N=103)

<table>
<thead>
<tr>
<th>Features</th>
<th>No.</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Adaptiveness</td>
<td>77</td>
<td>75%</td>
</tr>
<tr>
<td>Decision Making</td>
<td>73</td>
<td>71%</td>
</tr>
<tr>
<td>Drill</td>
<td>61</td>
<td>59%</td>
</tr>
<tr>
<td>Assessment</td>
<td>36</td>
<td>35%</td>
</tr>
<tr>
<td>Spatial Reasoning</td>
<td>26</td>
<td>25%</td>
</tr>
<tr>
<td>Synchronous Playing</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Physical Control</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Thus, acknowledging what is missing and what needs to improve in the current mobile games in mathematics, our design of Math Maze draws on several theoretical perspectives in the field of education: the multimodality of children’s learning, the constructivist theory, and the situated learning theory. In line with the expanded notion of texts in “multiliteracies” in different subjects under a burgeoning social context of globalization and digitalization (New London Group, 1996), Kress (1997) argues for "an absolute fact of children's semiotic practices" built on children’s multisensory learning theory (1997, p. 137) – children happily combine various semiotic systems such as talk, drawing, gesture, dramatic play, and writing during their learning experiences. Scholars (e.g., Gardner, 1983; Kress, 2003; Mayer, 2001) further assert that multiple communicative modalities with the intervention of technology enhancement start to redefine contemporary teaching and learning, and given that each medium has unique affordances and representations, meaning making happens cognitively through each unique mode of semiosis to support students multi-faceted learning.

Constructivist theory (Bruner 1986; Piaget 1977; von Glasersfeld 1995) is one of the perspectives underlying the theoretical framework of our study. In the constructivist approach, learning is an active process where learners actively construct and shape new ideas and understandings based on their current and prior knowledge. According to constructivist theory, learners continuously update their preexisting knowledge repertoire through their experiences with activities. Constructivist activities are designed to meet learners’ unique needs with multiple options provided. Situated learning theory (Brown, Collins, & Duguid, 1989; Wenger, 1998)
also contributes to our theoretical perspective. It posits that learning takes place in authentic contexts. Situated learning theory is complementary to constructivist theory in a mobile learning environment. Learner’s active participation, open-ended learning goals, context-aware learning, project-based learning, and case-based learning can be all realized through mobile technologies that support learners’ knowledge construction in an engaging manner (Ahuja, 1994). Thus, Math Maze builds on the theoretical concepts of children's multisensory (Kress, 1997) and multifaceted learning (Gardner, 1983) as well as students' situated learning in a gaming environment (Gee, 2003), while acknowledging its potential assistance for teacher instruction, as Darling-Hammond (2010) asserts that learning from the wisdom of teaching practice plays a central role in improving conventional and alternative routes to teacher education. The design of Math Maze is further guided by Klopfer (2008)'s game design principles for supporting 21st century skills in navigation, sustained reasoning, complexity management, collaboration, as well as planning for the unexpected. Furthermore, Math Maze acknowledges students' differentiated learning and presents adaptive mathematical challenges to individual students, letting game player's answer to a previous question direct the next question.

4. Contribution to the field of Mobile Learning:

The growing impact of mobile gaming on students’ learning cannot be underestimated by educators in today’s mobile networked society. We believe that learning happens everywhere, not just limited by classroom and the conventional instruction through face-to-face and print "modalities". The first national survey of its kind conducted by the Pew Internet & American Life Project finds that virtually 97% of American teens (17 million) aging from 12 to 17 play computer, console, or cell phone games, and 48% of them use a cell phone or handheld organizer to play games (Lenhart et al., 2008). The commonplace for gaming and students’ learning has generated considerable opportunities for educators and technical developers to utilize the unique features of mobile technologies for new options of learning. However, few opportunities of mobile learning have been provided to young children and teachers of this group so far. Thus, our project contributes to both the literature and the development of adaptive functions and mechanisms and data mining system of current iPhone applications in the subject of mathematics for young children. The project further contributes to the understanding how teachers, parents, and students from K-2 perceive and/or take up a mathematical mobile learning tool (Math Maze) in and out of school. Though most of the games we analyzed in our background study do not address students’ diverse learning preferences and intelligences, educators should consider how to selectively implement mobile games into their pedagogy to support situated learning. In this way, learners can be exposed to a mode of learning that: 1) caters to students’ multiple ways of learning, 2) facilitates the development of multiple intelligences, and 3) prepares them for a lifetime of learning through media-rich environments. And teachers can better utilize mobile games to evaluate students' learning and accordingly improve teacher instruction.

5. Feasibility/Potential for Scale:

We believe there is tremendous potential for widespread distribution and adoption of Math Maze both in and out of school. In particular, the literature (Ginsburg et al., 2006;Ginsburg, Lee, & Boyd, 2008; Lee & Ginsburg, 2009; Lee & Ginsburg, 2007a, 2007b) highlights: 1) the need for additional mathematics learning opportunities for young children; 2) the potential for technology
to enhance informal math learning, 3) the challenges of adaptive/personalized mathematics instruction, and 4) the demand for more research on the teaching of mathematics instruction. Our proposed project will make significant contributions to each of these domains.

Once the application is fully developed, launched, evaluated, and redesigned, it will be very easy to mass produce, market, and distribute the application. Specifically, our team will utilize popular distributions channels (e.g., Apple App Store, YouTube) as well as the vast network of Teachers College affiliates and partners to disseminate the application.

We envision the following major activities as part of implementation:

1) Place Math Maze on the Apple App Store. Math Maze will be available for free download to any user. The full version of Math Maze can be purchased for $4.99.
2) Launch a Math Maze website that features the research on which the application was developed, findings from the evaluation, and student/parent/teacher testimonials.
3) Promote the use of Math Maze in pre-service programs at Teachers College.
4) Promote the use of Math Maze in Teachers College affiliated schools in the U.S. and abroad.
5) Raise awareness of Math Maze through a viral marketing campaign.
6) Publish the findings of our Math Maze application.

6. Next Steps:

Funds from the Grand Prize will initially be used to enhance, implement, and evaluate Math Maze. In order to accomplish this we will hire a part-time mobile application developer and a part-time interaction designer to work with our full-time staff. After a full prototype is completed, we will use the funds to develop the technological infrastructure to support the Math Maze. Examples include: a) Apple Developers Account, b) a classroom set of iPod Touches, and a c) server optimized for virtualization. Simultaneously, we will hire a group of researchers in order to evaluate the tool and publish stories about Math Maze. Based on the findings of our study, our development team will make modifications to the tool. Once Version 1.0 is complete, we will hire a group of designers and video producers to create all the marketing and promotional materials. The researcher team will then conduct targeted outreach efforts with groups at and outside Teachers College in order to promote its use by learners and teachers.