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ACCOUNTABLE GAME DESIGN: STRUCTURING THE DYNAMICS OF STUDENT LEARNING INTERACTIONS

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ABSTRACT

Game-based classroom activity is intended to leverage students' interest and motivation to play, and to provide safe contexts for supporting students' academic learning. However, a basic criticism of many games currently used in classroom settings is that they can fail to meaningfully embody academic content. A more subtle concern is that cognitive and social dynamics emerging from the structuring and enactment of poorly designed games may compromise students' affective disposition and, so, undermine their learning opportunities. Using the case of classroom games designed for mathematical learning, I propose to examine how certain structural dynamics of a learning activity such as the rules and protocol for interaction, choice of media, or criteria for success may influence student interest, engagement, and eventual learning outcomes. This theoretical article reviews cognitive, developmental, and game-related literature in order to develop a rationale for *accountable design*—an approach that considers how these dynamics may be coordinated to support both the instructional objectives of educators, as well as the individual social and developmental needs of students.

BACKGROUND AND OBJECTIVES

A general strategy for supporting classroom learning has been to design/organize play-based activities such as games (Dewey, 1928; National Council of Teachers

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of Mathematics [NCTM], 2000). An explicit rationale for game use is to engage students in instructional contexts they find both motivating and that elicit their personal interest (Kafai, Franke, Ching, & Shih, 1998). Interest and motivation, in turn, impact an individual's level of activity, engagement, and willingness to persist (Pintrich, Marx, & Boyle, 1993). Therefore games—activities that students appear naturally motivated to participate in—present prima facie viable contexts for the design of learning activities. Indeed, a plethora of recent studies demonstrate the effectiveness of games as contexts for learning mathematical content knowledge and concepts (see Kamii & Rummelsberg, 2008; Ramani & Siegler, 2008).

However, it is important to note that games—not unlike many traditional classroom practices—have also been observed to *negatively* influence student/classroom learning outcomes. A basic observation is that some games designed for educational purposes lack clear educational content or objectives (Fisch, 2005). Another, is that students playing a game might overlook or misinterpret the intended "learning objectives" of a game entirely (Rieber, 1996; Turkle, 1995). A more subtle concern however, is that games used for the purpose of supporting student learning have been shown to produce deleterious effects on student attitudes (see Bandura, 1986; Bragg, 2007). For example, games that reward students for knowing answers faster than their opponents are liable to undermine most students' sense of self-efficacy, because students are generally sensitive to their academic aptitudes relative to others (Wentzel, 1991).

Such observations suggest that design rationales for implementing games in classroom settings remains under-theorized. A further symptom of this under-theorization is that many game designs fail to consider the diverse needs of a spectrum of students that can include at-risk populations as well as individuals with special needs or learning styles. Clearly, it is self-defeating if a game (or any other specially designed intervention for that matter) intended to motivate students to engage with academic content, were to: a) fail to effectively convey academic content to students; or b) discourage them from participating in a learning activity entirely (Charoenying, 2008; see also Barron, 2003).

The purpose of this review will be to develop a theoretical rationale for the design of what I refer to as *accountable games*—playful learning activities that take into consideration both the learning requirements and goals of the educator; and the social, cognitive, and developmental needs of the learner (Charoenying, 2008). By accountable, I take to mean an obligation and responsibility to honor the content and standards that educators and administrators alike are beholden to, as well as to respect the individual aptitudes and experiences of the students themselves. Accountable design purposefully considers how a game's rules, artifacts, and modes of organization structure inter- and intra-personal contexts and interactions. One hypothesis, for example, is that students with negative academic experiences in mathematics might be further discouraged by games or other activities such as assessments that depend on speed of recall for success.

Developing and testing such a framework might potentially allow educators and researchers to better match learning dynamics based upon students' particular affective and/or academic orientations.

An objective of this work is to help explicate what might otherwise be *tacit* design considerations in order to illuminate opaque elements in the craft of educational design (see Abrahamson, 2009). This is part of my broader goal of delineating, developing, and researching principles of design that can influence student learning and applying these principles in the design of developmentally appropriate contexts for learning, which also include classroom tools, materials, and practices.

The review will begin by examining themes in the cognitive and developmental literature that support the use of play activities such as games. It will then consider trends in game design theory, and the various attempts that have been made toward classroom application. Next I will present and articulate principles of accountable game design, and examine how these principles have been applied to a proof-of-concept game of my own design called *Math Agent*. Using this case of a classroom game designed for mathematical learning, outline how specific *structural dynamics* of a learning activity, for example, the designed rules and protocols for interaction may influence social and cognitive engagement in an instructional game activity. I will conclude with a brief reflection on the role that the game design principles apply toward more traditional classroom activity designs, and an outline of directions for future empirical work.

PLAY AND GAMES AS CONTEXTS FOR LEARNING

I begin the inquiry into accountable game design by establishing a distinction between *play* and *games*.

Play and Its Purposes

There is no one definition of play. The *Meriam Webster's Dictionary* provides over a dozen definitions of play that are each dependent upon a specific context and situation. Indeed, Sutton-Smith (1997) begins his examination of play by stating that among scholars of play there is "little agreement, and much ambiguity" in regards to a definition of play (p. 1). He goes on to elaborate how, in defining play, theorists across fields as interwoven and diverse as biology, economics, literature, psychology, and sociology focus on different conceptualizations unique to their individual discipline. The sociologist Huizinga (1949/1938), for example, argues that the entirety of human civilization is proof and product of play, with everything from rites and rituals across music, art, politics, and warfare being an expression of the play ethos. Yet, whereas scholars who study play may be in disagreement over a technical definition, there is a general and growing consensus that play has an important role in human development.

Developmental psychologists have long argued that play activities support human (and animal) growth and development (Bruner, 1972; Erikson, 1950; Piaget, 1962, Power, 2000). Piaget (1962) believed that play represented an opportunity for children to assimilate new events, objects, or situations into existing ways of thinking. Play was seen as a context for the spread and development of social artifacts such as rules and systems of morality (Piaget, 1965). Similarly, Bruner (1972) suggested that play "can serve as a vehicle for teaching the nature of a society's conventions, and it also teaches the nature of convention per se" (p. 699).

Vygotsky (1978) goes further to describe play as the "leading activity that determines the child's development" (p. 103). Specifically, Vygotsky believed that parental engagement in imaginary play situations introduces the child to social artifacts such as language, concrete tools, and representations (see also Vygotsky, 1966).

In summary, among researchers of the development of identity and cognition, there is a general consensus that play forms an important, if not essential, role in an organism's physical, emotional, and social growth and well-being (see Power, 2000). Play allows individuals to explore issues related to personal and social identity, and serves as a context for children to learn about social tools such as language, and social conventions such as morality (Bruner, 1972; Piaget, 1962; Vygotsky, 1966, 1978). Given this apparent centrality of play to human development, a number of educators, psychologists, and researchers have advocated the use of play activities for both therapeutic and instructional purposes (e.g., Erikson, 1950; Power, 2000; Rubin, Fein, & Vandenberg, 1983). We will focus on the instructional affordances of structured play contexts known as games, with a specific emphasis on how the rules and conventions of interaction delineate and determine the social interactions and experiences of the players.

Defining Games

The *Meriam Webster's Dictionary* defines games both as "an activity engaged in for diversion or amusement" and "a physical or mental competition conducted according to rules with the participants in direct opposition to each other."

Contemporary game design theorists Salen and Zimmerman (2003) categorize games as a formalized subset of play (p. 72). Vygotsky (1978) describes games as play activities that include socially agreed upon rules. He regards games as specialized forms of play, and further defines games as "purposeful activity" for children, with clear, definite outcomes such as winning or losing, finishing first or last (Vygotsky, 1966; see also Huizinga, 1949/1938; Piaget, 1965). Similarly Dewey (1928) highlights the importance of rules to a game, suggesting that, "without rules, there is no game" (p. 52). Games can thus be conceptualized as play activities that are structured and organized around socially defined artifacts, instruments, and rules. Therefore, when designing a game, one essentially designs a context of play, and by extension, a context for situating learning (Gee, 2003).

Games and Learning

Games have long been used for learning purposes within and without the classroom. Games such as chess have been used since medieval times to cultivate strategic and military thinking (Vale, 2001). Games have been specially designed to teach classroom subject matter (e.g., Bright, Harvey, & Wheeler, 1985) as well as skills and concepts relevant to specific professional domains (Michael & Chen, 2005).

Presently the commercial video and computer game market has matured into an economic and cultural force rivaling the movie industry in terms of scope and scale. Not surprisingly, video games and computational media are being touted in educational circles as powerful tools for creating supportive learning environments for students (see Barab, Zuiker, Warren, Hickey, Ingram-Goble, Kwon, et al., 2007; Gee, 2003; Holland, Jenkins, & Squire, 2003; Shaffer, 2007; Squire, 2002). Indeed, branches of the U.S. Armed Forces now employ video game simulations as both recruitment and training tools (Michael & Chen, 2005).

Parallels to Successful Classroom Interventions

Given that student objectives in school are often oriented around social, as opposed to academic goals (Wentzel, 1991), classroom games may present useful opportunities to organize student interactions around classroom learning objectives. A major theme for supportive classroom intervention is situating learning within contexts of personal interest that students can positively identify and engage with (i.e., Ladson-Billings, 1995; Lee, 2003). What individuals learn is, as Lave (1988) and Lave and Wenger (1991) demonstrated, greatly influenced by the intersection of needs, situations, and social interactions. Furthermore, as Brown, Collins, and Duguid (1989) argue, learning takes place through enculturation in authentic contexts, and social situations provide students with the opportunity to observe, imitate, acquire, and apply behavior and belief systems. A well-designed game might potentially serve as a viable social context to situate student learning within the classroom.

Other successful classroom strategies such as *reciprocal teaching, jig-sawing*, and *Fostering Community of Learners* (Brown & Campione, 1992; Palinscar & Brown, 1984) rely on actively engaging students with purposeful group roles and responsibilities around content. The bases of motivation in these activities are: the personal interests, voices, and opinions of students, and the social expectations of the group dynamic that the educator has deliberately structured. Cooperative group work approaches further support individual learning by leveraging the shared expertise and distributed cognition of individuals in relation to the group (Bransford, Brown, & Cocking, 1999; Cohen, 1994). An individual has the opportunity to learn new ideas and verify or challenge existing notions through interactions with more or less knowledgeable others. Similarly, games can provide students with purposeful roles, objectives, and foster legitimate peripheral participation around an academic subject (Lave & Wenger, 1991). Students learn the rules, conventions, and etiquette of a game by interacting with and observing one another (Piaget, 1965), and ideally learn content that is relevant to their schooling.

Guarded Potential of Games

At their best, games present opportunities to situate students in meaningful academic content in a way that is personally motivating, engaging, and less threatening to student's academic self-esteem and affective dispositions than "traditional" forms of classroom instruction (i.e., Barab et al., 2007; Coleman, 1972; Shaffer, 2007).

On the other hand, poorly designed or improperly utilized games may have a deleterious effect on student affect, esteem, or interest in an academic subject (see Bandura, 1986; Bragg, 2007; Charoenying, 2008). Furthermore, if students fail to learn "academic content" from a game design, it is difficult from the perspective of a classroom educator to justify its use. As such, what is needed still is a comprehensive framework for understanding how the structuring and design of a game, influences both inter- and intra-personal dynamics. To do so, it is useful to examine games as they are presently designed, from the perspective of both theory and application.

GAMES:
THEORY AND APPLICATION

Classroom Games

Games that are used in classrooms typically fall into two distinct categories of use. The first category of games are games that have been designed purely for *recreational* purposes. Within the classroom, such activities are often provided to students as incentives to complete assignments, rewards for behavior, or simply as a means to pass the time. A subsection of these include *culturally embedded games*—broadly disseminated socio-cultural artifacts (e.g., Piaget, 1965) such as chess—that were originally designed without classroom learning objectives in mind at all, but which are seen as possessing intellectual—and by extension, academic—merit, and have thus been appropriated for classroom application. Studies on the situated nature of mathematical learning in non-traditional contexts such as basketball, dominoes, and *Monopoly* lend support to the idea that many games not originally intended for classroom use do actually provide useful contexts for learning (e.g., Guberman, 1999; Nasir, 2002). A number of researchers have extended these claims in favor of using tools such as video and computer games as a means to situate student learning (see Gee, 2003; Shaffer, 2007).

A second category is that of *instructional games* (Bright et al., 1985), playful activities designed with *explicit learning objectives* in mind. Examples of this genre can include instructionally-oriented board, card, or computer games, as well as the various lessons and activities designed by teachers, curriculum writers, and instructional providers that purport to "make the activity of learning fun." Teachers routinely transform lessons into game-like competitions a là the popular television quiz show *Jeopardy,* and many commercially packaged mathematics curriculums include sections for games. And as has become the case for many commercially designed games, digital media have been adapted for instructional purposes.

Attempts have been made to marry the recreational and instructional qualities of games into a hybrid-class of products euphemistically referred to and marketed as "*edutainment*." This is a somewhat misleading term because, from the perspective of a game designer, all games are educational given that a player must learn how to play the game itself (Gee, 2003; Koster, 2004), but all games may or may not be entertaining. Others have used the term "*serious"* to games to reflect both the intensity and fervor that a player can invest into playing a game (Rieber, 1996), as well as "non-entertainment" objectives of some games such as to support military or medical training (Michael & Chen, 2005).

Instructional Game Design Theory

Game use for instructional purposes has a long established tradition dating thousands of years. However, systematic attempts at codifying the design and development of instructional games for classroom use did not emerge until recently. In one of the first large-scale studies ever done on instructional game use, Bright and colleagues (1985) identify and outline four considerations as critical for instructional games:

1. Characteristics of the game
   a. The format of the game (e.g., the game is a path game)
   b. The constraints imposed upon the players by the game (e.g., the game limits the ability of players to move their game markers)
   c. The responses required (e.g., players must write and solve a linear equation in order to make a game move)
   d. The size and complexity of the state-space
2. Instructional objectives of the game
   a. The content of the game (e.g., multiplication basic facts)
   b. The instructional level of the game (i.e., pre-, co-, or post-instructional)
   c. The taxonomic level of the game (i.e., knowledge, comprehension, application, analysis, synthesis, or evaluation)

3. Learner–game interactions during game playing
   a. The problem-solving heuristics elicited (e.g., looking back)
   b. The game-playing strategies employed (e.g., the selection of a playing space which produces the highest score for a single turn)
   c. The cognitive and affective outcomes which accrue to the player and their relation to attainment of the instructional objective of the game
   d. The amount of short-term and long-term memory loading that occurs
4. Learner–learner interactions during game playing
   a. Level of competition
   b. Peer instruction

(Bright et al., 1985)

Their framework suggests a correlation between the characteristics of a game's design, the instructional objectives of the game, and the interactions between the players with the game and with each other, to the learning experience of players. The original focus of the study was to analyze the effects of controlling for the instructional level and taxonomic objectives of a game and the correlation to classroom achievement, a first in the field of instructional game research.

However, a weakness of this design framework from a purely pedagogical perspective is that the needs and experience of the learner are represented as tertiary to the characteristics of the game itself. The learner–game interactions described suggest that the designer should consider how students respond to the design, as opposed to designing with the individual needs of the students in mind first. Additionally, they neglect to examine how the game characteristics they identify such as the format, constraints, and complexity of the game function vis-à-vis the developmental level of the learner, and how those design choices influence the affective dispositions of students.

Subsequent attempts at instructional game theory in ensuing years have focused primarily on the development of design methodologies for computer and video games. Rieber (1996), for example, highlights the manner in which content is presented to students. He describes an *exogenous* game design as one in which the primary objective of the game is clearly to interact with and learn content. In contrast, in an *endogenous game*, content is perceived as a secondary mechanism for achieving game objectives. Rieber argues that games should be designed so that students immerse themselves in a story and see the playing of the game as an objective in and of itself, as opposed to the game being a "sugar-coated" alternative to traditional classroom instruction. Miller, Lehman, and Koedinger (1999) state that game developers must be clear about expected learning outcomes, how they are to be assessed, and how they are to be explored by students within and without the context of the game. Their study suggests that structuring and orientation of a game's goals and objectives can influence student learning, a major theme that has arisen across both human–computer interaction and classroom-learning studies (e.g., Schank, 1996).

This more nuanced understanding of the relationship between game objectives and player interest has corresponded to more sophisticated attempts to bridge traditional and game based instruction. Squire (2002) has utilized commercial video game series such as *Civilization*[1] to introduce and discuss historical themes and content. He uses the affordances provided by the game to create opportunities for students to develop connections between the themes and content represented in the game, and the factual historical record as it pertains to complex ideas related to economics, politics, and urban planning. Shaffer (2007) advocates the use of computational technology to enhance real world learning. His *epistemic game* construct is intended to encourage students to emulate the dispositions, frames of mind, and practices of real world professionals such as architects, engineers, or journalists, by complementing classroom practice with professional tools, techniques, and technology. In an epistemic game, the ecology of interaction is not self-contained within the computer program, but is extended to include real-world connections to the adult-professionals working in the fields being modeled, as well as personally meaningful events such as student-led art shows and exhibitions.

Commercial Game Design

Contemporary literature on game design theory considers game elements such as the importance of "story, "balance," and "surprise." Crawford (1982/1997) for example outlines a taxonomy of games, the notion of embedding a fantasy story arc into the game play narrative, and articulates ideas such as the "smoothness of learning curves," and the "illusion of winnability" in regards to the threshold of difficulty in learning a game as critical to successful game design. Designers such as Koster (2004) argue that the human brain is designed to recognize patterns, and that part of the "fun" and appeal of a game is in attempting to identify them. A game such as tic-tac-toe is only "fun" as long as the patterns for success remain unknown. Once a pattern becomes too familiar, a player loses interest, and it is thus the constant challenge of designers to reinvent increasingly novel or complex dynamics of interaction. Salen and Zimmerman (2003) provide a comprehensive examination that explores how rules of play structure the interactions and experience of a game. Their analysis attempts to identify principles universal to all games—from traditional, board, card, or computer and video—in order to arrive at a unified, coherent methodological approach toward designing interactive game experiences. They present a systematic rationale for implementing sophisticated story-telling elements of plot, narrative, and even the emotional impact into a game.

As is true with other media such as film and television, there are many different genres of games, and many different philosophies of game design. Technology

[1] *Civilization* is a long running commercial game series designed by Sid Meier.

also plays a role: each new iteration of a game system or improvement in computational processing power provides new affordances, and consequentially new expectations for game play to evolve and innovate. Driving much of the innovation are professional game developers who test their ideas out in the crucible of the commercial marketplace. Commercially viable designs are often imitated and elaborated upon—by competitors and the game-playing community itself—whereas unsuccessful ones are discarded. The result is a "natural-selection" of sorts, whereby market forces and consumer choice shape the direction of future game designs. Not surprisingly, many instructional designs are patterned after commercial game designs and their underlying theory. The idea is to emulate the principles of design that professional game developers have successfully used to engage game players in rigorous, long-term, complex problem-solving endeavors. One potential danger, however, is that many of these discussions seem to stray from the experience of the student as a *learner*, and tend to focus more on the experience of the student as a *player*.

While elements of sound game design interaction, novelty, narrative, and most certainly the basic idea of "fun" are important to a student's immediate experience while playing a game, most commercial game theory neglects to explicitly connect these ideas back to student learning, and provides little to no contingency for the diversity of student interests and ability levels. This is frankly an issue of economic viability, because a game company depends on the commercial success of its design. Michael and Chen (2005) note that in comparison the market for educational games—and by extension, the proportion of funding and resources—pales in comparison to the market for commercial ones. Consequentially, most funding for game research and design is directed toward the production of games that appeal more to the interests and wants of the consumer marketplace, and less toward aligning designs to meet "classroom" educational objectives.

The Gap between Game-Play and Classroom Instruction

While interest and engagement with a game are important factors if students are to invest time and attention in playing, and potentially learn through a game, it is vital not to lose sight of the instructional objectives of games if they are to be used in the classroom. A long-standing criticism common to instructional games is that many fail to embody *transparent academic content* that meaningfully connects students to the content and disciplines they are studying in school (Dennis, Muiznieks, & Stewart, 1979, in Bright et al., 1985; Fisch, 2005; Rieber, 1996). No matter how motivating a game design may purport to be, it has a dubious place in an instructional context if it fails to align with the instructional objectives of teachers, administrators, and the curriculum in general.

Additionally, while many advocates of games believe in, and are quick to cite the positive impact that games can have on student interest, motivation, and in many cases, learning (Kamii & Rummelsberg, 2008; Ramani & Siegler, 2008), skeptics and educational "pragmatists" may easily point out the fact that there is as of yet no definitive, conclusive proof that games are a "best way" to instruct students, and that games can in certain cases produce a negative effect on student learning (Bragg, 2007).

Thus while proponents of video games such as Gee (2003) or Squire (2002) argue that games can teach sophisticated concepts such as physics, evolution, or social studies, it has also been observed that students may develop causal mechanisms for in-game occurrences that have nothing to do with the "educational concept," a point that seriously threatens to undermine the argument that students will learn the sophisticated concepts that designers implement (Turkle, 1995). Instead of learning a concept such as evolution, for example, a student might learn "to press button x whenever situation y occurs." Game researchers themselves concede that a game in and of itself is limited in its classroom application, and that it can be difficult to predict what a student may learn from playing a game (Barab et al., 2007; Bright et al., 1985; Miller et al., 1999; Squire, Makinster, Barnett, Luehmann, & Barab, 2003).

The more pressing concern to designers should be the fact that mechanisms of a game design itself can potentially discourage students from participating. Bragg's (2007) study of elementary student game play revealed student's attitudes toward and opinion of a particular game intervention actually becoming lower over time. A number of studies have demonstrated that game preferences can be a function of gender differences, with certain types of game play being more or less appealing to girls than boys, or vice versa (see Jenkins, 1998; Kafai, 1998), and it has been variously suggested that boys seek direct competition, and that girls tend to favor more collaborative, larger group interactions with open-ended objectives.[2] Rather than encouraging students to learn, one risks incurring the opposite.

Consequentially, it is important to consider precisely how the characteristics and dynamics that are structured into a learning activity such as a game, influence student attitudes, dispositions, and learning (Charoenying, 2008). Given that games—as simple as tic-tac-toe, or as complex as a massive, multiplayer computer world—are constructed artifacts, these are ultimately issues of design, and I would like to submit that a gap exists in our understanding of how to best design and utilize games for classroom contexts.

[2] It should be noted that gender stereotypes of game play are not rigid, and researchers have observed noticeable shifts in game play patterns across traditional gender roles (Eifferman, 1972; Inbar & Stoll, 1970; Kafai, 1998; Sutton-Smith, 1997). Casual observers of sports know that there are now female athletes competing in nearly every field of athletic pursuit, a feat that was once considered far-fetched and unimaginable.

If the positive affordances of play and games are to be fully realized in the context of the classroom, then a deeper, more reflective approach to game design and utilization is warranted.

TOWARD A FRAMEWORK FOR ACCOUNTABLE GAME DESIGN AND UTILIZATION

Given the incomplete state of the art, we arrive at the necessity for advancing a theoretical framework of design that considers game design and utilization from both the perspective of a classroom educator and game creator. As has been stated previously, it is unacceptable to design a game purportedly for classroom use that is "fun," but has no implicit or explicit instructional value; nor is it acceptable to fail to consider the effects that a game can have upon the affective dispositions of students to participate and learn.

While it may be difficult, if not impossible, to design for all contingencies, it is the responsibility of the conscientious instructional designer to be as deliberate as possible in considering the range of students who may be interacting with their games. This responsibility extends equally to the classroom educators who intend to utilize or create game activities with and for their students.

I propose then to outline a framework for *accountable game design.* This framework does not presume to prescribe best principles of game design. As surely as there is no one definitive way to write a book, paint a picture, or produce a movie, there is no one best way to design a game. Instead, this work is intended to highlight what I believe are key structural dynamics common to all games—commercial, instructional, pen-and-paper, recreational, computer-based, or otherwise—and explore how these insights can be applied toward the design of developmentally appropriate classroom tools, materials, and practices.

What differentiates this framework from prior attempts at instructional game theory is that it attempts to identify how specific game mechanics and elements of game design relate to and can influence the learning outcomes of individual students. Central to this work is the belief that the design should accommodate and adapt to the needs of the intended audience, and that the purpose of an instructional game is to convey learning objectives that are relevant to the work of classroom teachers and students alike.

The accountable game principles are intended as a rubric that can be revisited throughout the design, testing, and evaluation of a game. They are not meant to replace or refute the existing theory on game design, but to compliment and enrich the practice of instructional game designers by calling attention to how design decisions may impact student-learning outcomes. Nor, it should be noted, are they fully definitive, as there are doubtless other dynamics to be identified and/or validated through future empirical scrutiny. Furthermore, these principles are meant to inform the practice of classroom teachers, as they may apply to traditional methods of instruction and assessment as well (see also Dickey, 2005).

The key points for consideration in an accountable game design are as follows:

A. Intended Audience
B. Learning Objectives
C. Group Dynamics
D. Complexity of Rules
E. Criteria for success
F. Protocol of Interaction
G. Choice of media

These points are conceptualized as interrelated within a designed system. For example, the "intended audience" should directly influence a designer's choice for complexity of rules, or criteria for success. Each point will now be elaborated on in turn:

A. Intended Audience: A Learner Centered Design Approach

When designing a game, one must first and foremost consider the needs of the intended audience. Although all design work takes into consideration the experience of the user at some level, it is important from the perspective of instructional designs intended for classroom use, to place particular emphasis on the learner's individual backgrounds and experience (Ladson-Billings, 1995). Bright et al. (1985) have argued that the content in a game should be at a level appropriate to the instructional level of the student. Beyond this, is the consideration that students with learning disabilities, special needs, or past histories of academic failure may not only be disadvantaged due to gaps in prior knowledge, but also possess deep insecurities and low sense of self-esteem and self-efficacy (Bandura, 1986; Stiggins, 1999). Conversely, considerations should also be made for the developmental needs of students in the middle of and at the opposite end of the academic learning spectrum. The requirements of an instructional design intended for high-school special-education students, for example, should differ radically from something intended for a talented and gifted elementary class.

In summary, when designing a game, one must always consider and continually revisit the differentiated academic and developmental requirements of the population one is designing for (Bransford et al., 1999). This principle also holds true for teachers who simply wish to use pre-existing game interventions with their students. Game design and use, as is true of any sound instructional practice, should begin with a consideration of the needs of the learner, followed by the learning objectives one hopes to achieve.

B. Learning Objectives: Transparent Instructional Content

An inevitable topic that must be addressed when designing a context for learning is the notion of "transfer" (see Detterman, 1993; Gick & Holyoak, 1983). While a comprehensive discussion of the term is beyond the scope of this article, it is important to disclaim that there is preponderance of empirical data that suggests that what an individual learns when engaged in an instructional context is unpredictable, and at times, contrary to what the designer intends.

One basic conclusion from the transfer literature is that clear, explicit instruction is often the most effective (Detterman, 1993). Therefore, when designing an instructional context such as a game, particular attention should be paid to how that content is perceived and interpreted (Fisch, 2005). While advocates such as Gee (2003) claim that video games are teaching players "something," as Turkle (1995) points out, what students actually learn when playing a game may have nothing to do with the designer's original "educational objectives."

Consequentially, a designer must clearly identify the intended learning objectives, and consider how those outcomes can be assessed (Miller et al., 1999). Rieber (1996) has previously described two categories of instructional games: *exogenous games* in which the primary objective of the game is clearly to learn content; and *endogenous games* in which content is perceived as a secondary mechanism for achieving game objectives. The argument presented here is that regardless of the objectives, clear, transparent connections to instructional content should be made, if not within the game itself, then outside of it, in complementary classroom activities.

A rudimentary illustration of this principle can be demonstrated with the game of tic-tac-toe (see Figure 1). Although many young students enjoy playing this game with their peers, there is little apparent instructional value. While one can argue that the game embodies mathematical principles, content, and an element of strategy (such as always pick—or avoid—the center square first), it is entirely plausible for most students and many classroom instructors to think about the game only in terms of Xs and Os.

Though it possesses discernable mathematical content, tic-tac-toe was arguably never designed with more than casual recreational intent in mind, and thus the endogenous or exogenous nature (Rieber, 1996) of instructional content is somewhat of a moot point. More transparent instructional content, however, might be introduced into the context of this game through complimentary explicit classroom instruction prior to or proceeding game play, or by modifying the game field itself (see Figure 2). This transforms the game into a context for teaching mathematical conventions such as the horizontal and vertical axis of a grid, or rudiments of the coordinate notation system.

The modifications to the game-grid and accompanying class lessons do not change the perceived objective of the game. What changes is the orientation of

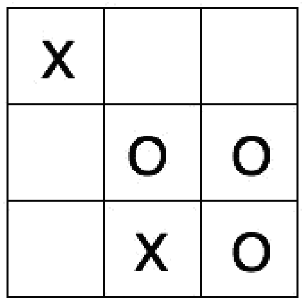


Figure 1. The familiar game of tic-tac-toe.

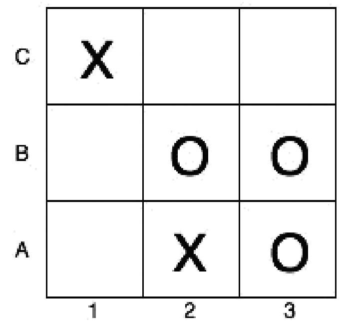


Figure 2. The tic-tac-toe grid with notations to support the teaching of the elementary level concept of coordinate grid reading

student activity around instructional content, and the ability of the teacher to more explicitly draw attention to instructional objectives while simultaneously allowing students to continue indulging in their recreational pursuit. Students would potentially be satisfied playing a game, and the classroom teacher or administrator might be satisfied knowing that a key concept relevant to reading maps, graphs, and tables was being taught to students.

While the example tic-tac-toe is simplistic, this notion of building instructional content both within and around a game design can and has been demonstrated with school-yard, board, card or computer games—in short, with virtually any and all gaming context (see Kamii & Rummelsberg, 2008; Ramani & Siegler; 2008; Squire, 2002). Though the goal of instructional game designers should be to create as effective an instructional medium as possible, it may be an unnecessary conceit for them to expect to design perfect, self-contained products that achieve their learning objectives independent of human intervention or interaction. The main point is that students must be able to clearly see the desired instructional outcomes of the game. If this objective is not directly accomplished within the design of itself, then it stands to reason that the classroom instructor, if not the instructional game designers themselves, can support the learning process with complimentary activities, lessons, and even homework that will explicitly highlight the intended instructional objectives.

C. Group Dynamics: Supporting Communities of Learning through Games

Educators must always be aware of how interpersonal interactions can influence student affective disposition (Bransford et al., 1999; Bright et al., 1985; Cohen, 1994; Slavin, 1980). While high-achieving students might thrive on and be motivated by the challenge of competitively structured games, an at-risk learner may be discouraged or intimidated from participating (Bandura, 1986). From the perspective of accountable game design, however, competitive, cooperative, and collaborative[3] interactions all influence how students might interact with one another, and the choice of which should be deliberately weighed against the needs of the intended audience and the desired learning objectives (Cohen, 1994). Research has shown that the effectiveness of cooperative learning environments is contingent upon the level and sophistication of the content being taught (Slavin, 1980). Therefore, a designer should also take into consideration factors such as age, ability level, gender, and the instructional content itself, and how they will influence and be influenced by the group dynamic established by rules of the game.

D. Complexity of Rules: Accessibility versus Depth of Game Play Experience

Games with simple rules are more accessible to players, but less capable of sustaining long-term interest (Koster, 2004). Games with complex rules can create barriers of entry such as a steeper learning curve, but cultivate a deeper, more sustained interest on the part of the player (Bright et al., 1985; Koster, 2004; Papert, 1998). This idea that the complexity of a game's rules can determine its accessibility, can be illustrated by comparing and contrasting two commonly played games: checkers and chess. Both are turn-based, competitive board games that are played by children in classrooms the world over. However, it might be safe to assume that more students in U.S. classrooms know how to play the former than the latter.

A large function of this may be the simplicity of the rules of checkers, which can be taught and learned in a short amount of time. In contrast, chess has such a deep and sophisticated level of complexity, that it was used as the basis for some of the first attempts to program computerized artificial intelligence (see Newell, Shaw, & Simon, 1958). One consequence of this deep sophistication and complexity though, is that many people never learn how to play the game properly, and as a result fail to take advantage of its widely perceived intellectual affordances. On the other hand, precisely because of, and not in spite of, its deep complexity, those who do take up the game of chess and overcome the steep learning threshold have been known to cultivate a life-long interest and passion for the game. There are numerous publications, books, professional leagues, and

[3] There is a slight but subtle distinction between the terms *cooperation* and *collaboration.* The *Meriam Webster's Online Dictionary* defines cooperate as "to act or work with another or others." To collaborate is to "work jointly with others or together especially in an intellectual endeavor."

associations built around the play of chess. Checkers, by comparison, has a much shorter "shelf-life." While it is easy to learn, the simplicity of rules ultimately limits the variations of game play. As the game designer Koster (2004) observes, the human mind enjoys the discovery and deciphering of new patterns, and once a game's patterns becomes too familiar, it loses its appeal.

An accountable game design must therefore weigh the affordances and trade-offs of a game's complexity in relation to the intended audience and instructional goals. Some instructional content may warrant the use of simple games to ensure ease of accessibility. Alternately, an instructional designer may choose to employ more complex, challenging designs that provide long-term opportunities for engagement. Many video game designs attempt to balance this tension by introducing progressively increasing levels of complexity. This simultaneously provides a lower barrier of entry for new players, as well as the higher ceilings of challenge needed to sustain long-term interest (Gee, 2003).

E. Criteria for Success: The Influence of Skill and Chance on Perceived Outcomes

Games of skill and chance have long held a place of fascination in human cultures (Huizinga, 1949/1938). A game of skill implies that human agency determines the outcome of a contest. Chess is an example of a game of skill in which—barring human error—the much stronger player will almost certainly, always defeat a less skilled opponent. In a game of pure chance, outcomes are completely random and uncontrollable. The winning and losing results of a game of bingo for example, is entirely determined by chance. There is no way—barring cheating—to control the numbers.

Bandura (1986) has argued that classroom practices that are competitions of skill, while theoretically positive experiences for the victors, can be deleterious to the esteem of the losers. Slavin (1980) describes *performance outcome* as one of the criteria that students judge their actions by. Generally speaking, because students are aware of their abilities relative to others (Wentzel, 1991), they can be easily discouraged from playing games based entirely on skill. This can be observed in classrooms or school yards, in which students develop preconceived opinions of who runs the fastest or is the "best" at a particular subject or game (Coleman, 1972; Piaget, 1965). Consequentially, students who are conscious of their deficiencies relative to others may only grudgingly choose to participate. If games were meant to motivate students to learn and participate, such negative outcomes would be self-defeating.

An accountable game design must therefore consider how the criteria of success in a game may influence the participation of the intended audience. Providing an element of surprise or chance for example might positively influence interest and participation by supporting the "illusion of winnability" (Crawford, 1982/1997). However, outcomes that are too random at one extreme, or too predictable at other, can also discourage sustained interest in game play (Koster, 2004; Vygotsky, 1966).

Ultimately, criteria for success is a design choice that must be weighed against the objectives of the game in relation to the characteristics of the students who will be playing it. It might be unwise (as in the case of chess) to pair students with different aptitudes in mathematics, for example, in a game based solely on skill. Alternately, two high achieving students might thrive on direct competitions of skill, and become disinterested by games with random outcomes. Conversely, two low achieving students might be presented a game in which chance plays the determining factor.

F. Protocol of Interaction: The Sequencing and Flow of Game Events

Most games can be conceptualized as possessing either *turn-based* or *real-time* interactions (Salen & Zimmerman, 2003). Chess, checkers, and hop-scotch are examples of turn-based games. In turn-based games, players are allotted designated opportunities to perform their specific game-related tasks. The flow of time in the real world is secondary to the order of operations and restrictions established by the rules of the particular game. Flash cards, the genre of "first-person shooter" video games, and the playground game tag are examples of real-time game play. Success or failure in real-time games is contingent upon reacting and responding to game events more quickly and more skillfully than one's opponent.

The protocol of interaction directly influences a game's criteria for success, and by extension, can influence the likelihood for students to participate. In the early rounds of the popular television game show *Jeopardy,* for example, a contestant's speed and timing at pressing a button in real-time is one of the primary determinants of success. However, in the final round, the protocol is changed so that all contestants have the same opportunity to answer the final question. While some element of speed is still warranted because the final round is timed, the criteria for success shifts from quick mental reflexes toward individual knowledge.

From an accountable design perspective then, the protocol of interaction may present another leverage point for accommodating the needs of learners, and should be considered in relationship to the intended audience. Slowing a game down, or alternately speeding it up, may potentially encourage or discourage students depending on their comfort level with the content or individual abilities.

G. Choice of Media: The Relationship between Games and Technology

Simply using a "hi-tech" medium such as a computer, does not necessarily add to or elevate the complexity of the game, nor change the fundamental interactions between participants that the rules of a game structure. The rules of the game of chess, for example, are the same whether or not the pieces and board are made out of tangible materials, or have been represented digitally.

What can change with and through technology are the range of interactions and conceptual possibilities of a game (Gee, 2003; Salen & Zimmerman, 2003; Squire, 2002). Advances in material sciences, engineering, and applied physics, for example, have led to the creation of better tennis rackets and golf clubs. This might alter the experience of play in terms of mental and physical speed and control, which can introduce a new level of complexity to the game. Modern video game players are now accustomed to more sophisticated modes of representation and interaction than the first "gamers" in the 1950s and 1960s. The Internet allows players from around the world to connect with one another. Inevitably, the expectations of game players (and students) evolve alongside with technology, much as a modern cinema viewer expects films to contain color, sound, and a storyline that pays homage to yet surpasses the benchmarks of the past (Juul, 2000).

While technology can provide many unique affordances such as helping to visualize scientific phenomena or simulating virtual environments (Barab et al., 2007; Shaffer, 2007), an obstacle that inevitably arises is one of access. Simply put, resource-poor schools and communities may lack the necessary funding or basic expertise needed to access technologically based interventions (Cuban, 1986). Another barrier is that training in the use of and comfort with technology is required to support classroom adoption by the teacher, and by extension the opportunity for students to interact with these resources as well (Squire et al., 2003). Consequentially, utilizing the newest, most sophisticated technological media for classroom-learning tools such as games may not be warranted if it presents an obstacle for implementation.

The utilization of computational technology must therefore take into consideration individual contexts and situations (Ackermann, 2003). Lack of access to technology at home or in the classroom, or a desire to foster direct, face-to-face interactions, may warrant "low-tech" designs such as card or board games. The potential to create interactive experiences beyond the limits of the classroom is but one justification for high-tech designs. As always, however, the needs of the intended audience and the desired learning objectives should guide the choice of media.

MATH AGENT: ACCOUNTABLE GAME DESIGN AS PROOF OF CONCEPT

Context Driven Game Design

The original inquiry into accountable design began as an attempt to understand why specific students—particularly those identified to possess a learning disability—failed to positively respond to a game-based remediation strategy. An examination of the game's dynamics led me to conclude that the protocol for interaction—speed—and the students' acute awareness of their inadequacies relative to others, were likely to blame.

In an attempt to remedy this predicament, I designed an instructional card game called *Math Agent* (see Figure 3 and Appendix A).

I originally chose a card format because I had observed that commercial card games were popular with many of the students at the school site, and because I wanted a technological medium that students could easily use at home, in the classroom, or in the playground. This decision was further warranted because many of the students did not have access to computers at home.

From an accountable design perspective, the commercial games that the students were playing lacked transparent instructional content. In other words, mathematics was involved, but only tacitly. That, combined with the high level of complexity of the game rules, made them unsuitable for general instructional purposes. Therefore, I had to create a new system of play to accommodate the needs of my intended audience (upper elementary students from in both general- and special-education classrooms) and my learning objectives (arithmetic and concepts from upper elementary mathematics standards). Following the accountable game design framework, the design principles guiding the game were as follows:

> **A. Intended Audience**:
> The intended audiences were 4th and 5th grade elementary students. The game was designed with a "low floor" and a "high ceiling" in mind to accommodate both special-need students and advanced upper elementary aged learners. The basic interactions were simplified to "attack" or "defend" vis-à-vis basic arithmetic, but the range and variety of cards provided opportunities for more advanced players to develop more sophisticated strategies.
>
> **B. Learning Objectives**:
> Intended for teaching/remediation/mastery of arithmetic operations, mathematical concepts and vocabulary from the 3rd, 4th, and 5th grade state standards. The educator's learning objective of arithmetic practice is (partially) transparent and sustained because every game interaction requires an arithmetic operation. The student objective however, is to "defeat" an opponent. An auxiliary objective was to familiarize students to more standardized vocabulary by exposure.
>
> **C. Group Dynamics**:
> Competition is leveraged as a means to motivate students to practice the game. However, knowing the risks of competition, the "protocol of interaction" and "criteria for success" were taken into account.
>
> **D. Complexity of Rules**:
> The basic interactions of "attacking" or "defending" using arithmetic was familiar and accessible to most of the students, and yet the number of possible combinations/permutations of cards and strategies provided the complexity needed for sustained interest.

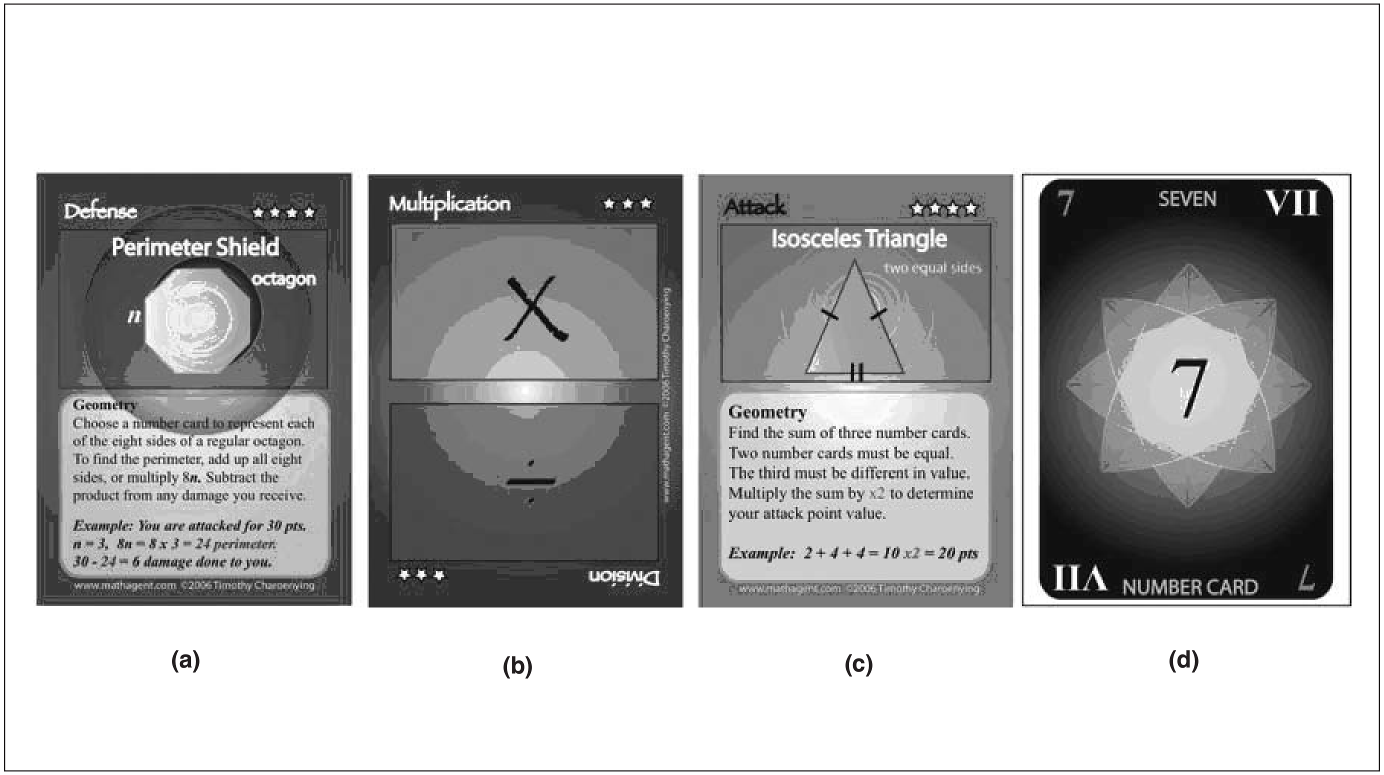


Figure 3. Sample cards from the *Math Agent* deck. a) A "*defense card*" using the terms *perimeter* and *octagon;* (b) a *multiplication/division* card; (c) an "*attack card*" using the term *isosceles triangle;* (d) a number card.

E. Protocol of Interaction:
Turn-Based. Individual speed-of-recall and reaction have no bearing on game interactions or individual success. This was done to support the play experience of special-education students, as they could leverage the distributed knowledge of the other player if for example, they did not immediately know that $5 \times 5 = 25$.

F. Criteria For Success:
As with most card games, skill is the long-run determining factor, but luck-of-the-draw plays a role. This mechanism was intended to support the motivation to play of less-skilled students against "superior" opponents. While the superior player would generally win more in the long run, the less skilled player might occasionally win due to a favorable hand of cards.

G. Choice of Media:
Playing-card format was chosen so the game could be played in the class, school-yard, lunchroom, or home, and would not require access to computers or the Internet. Additionally, direct inter-personal interaction and the affordances of peer-supported learning were desired objectives of the game, as part of the strategy was to foster "communities of mathematical practice" (e.g., Ball, 1995).

From the anecdotal evidence, one individual stands out in particular, a fifth-grade special-education student who had been held over from promotion, twice. Typical of students who are repeatedly faced with learning failure, the student was withdrawn and reluctant to engage in traditional attempts at remediation. Game-based strategies that relied primarily on speed of recall/response as the criteria for success only served to further discourage the student from participating. Using *Math Agent* as a peer-supported intervention, the classroom teacher observed a dramatic shift in the student's basic computational abilities as well as his affective disposition toward mathematical content. Another unexpected development was that the student's *father* took an active interest in the game, so much so that he would play it nightly with the student.

Although the *Math Agent* design appears to potentially impact procedural knowledge and disposition positively, a closer analysis is required to determine whether participation in the game indeed effects improvement in conceptual understanding, and encourages mathematical reasoning to develop. One known possible tradeoff is that the competitive structuring of the game often appealed to boys more than girls. Another concern was the tentativeness that *teachers* displayed in implementing the game intervention without the support of the researcher, which may be a function of the perceived complexity of the game design.

Present research in progress is aimed to determine relations between the accountable-design principles and the effects of participation in *Math Agent* and other game activities. An a priori hypothesis is that there is a correlation between individual student's sense of self-efficacy (in regards to the particular academic subject) and the structural dynamics of a game. In other words, I believe that students' preference for specific game interactions is correlated with their individual assessments of their own ability. Additionally, I am interested in observing and measuring changes in mathematical self-concept and self-efficacy over time, as well as trying to identify any emergent social phenomena, such as player-to-player mentoring and problem-solving strategies. In order to address some of the limitations of the original *Math Agent* game, I have reflexively applied the accountable design framework in order to create a broader set of game activities that can better accommodate a greater range of participants.

SUMMARY AND CONCLUSION

Using the case of classroom games designed for mathematical learning, I have attempted to articulate a rationale for understanding how the *structural dynamics* of a learning activity such as a game influence student participation and engagement in an instructional activity. This framework is intended to support the design of instructional games by highlighting the interactions between the social and developmental needs of students with game elements such as skill, chance, speed, and complexity of rules.

I have chosen to examine games because of their meaningful role in the social and developmental lives of children and adults (Power, 2000). This universal appeal positions games as potentially powerful tools for motivating students to participate in instructional activities (Dewey, 1928; NCTM, 2000). I believe that by better understanding the mechanisms in play when students are engaged in a learning activity such as a game, we as educators will be better positioned to structure other contexts for learning as well.

To conclude, it has been argued that a major failing of public education over the past century has been its neglect of the uniqueness and diversity of cultural practices, experiences, and backgrounds of individual learners (Ladson-Billings, 1995; Lee, 2006a; Ogbu, 1989). A consequence of which is the continued existence of an achievement gap that is clearly demarcated along racial and socio-economic lines (NSB, 2008; Steele & Aronson, 1995; Sirin, 2005). While it is beyond the power of educators to enact immediate change at the societal level, it is within our ability to design supportive contexts for learning within the classroom.

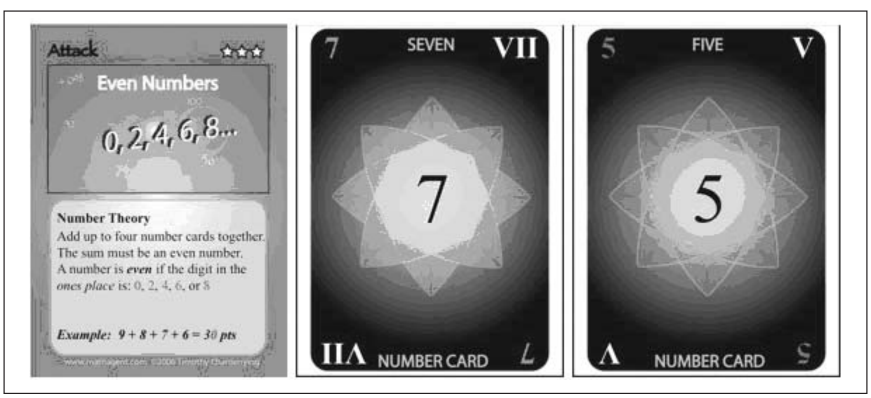
If the means to overcome the achievement gap is as Lee (2006b) suggests, to foster and cultivate the simple joy of, motivation to, and wherewithal for learning itself, then we must be willing to consider exploring new strategies for structuring the contexts for learning. This will require a more critical and nuanced understanding of how basic design decisions influence students' affective dispositions toward learning. While I believe that play and games may provide meaningful social contexts for learning within schools, at the same time, I believe that games—as well as any instructional context for that matter—must be accountably designed to meet both the academic standards we wish to uphold, and to the individual learning experiences of the students themselves.

APPENDIX A
Basic Math Agent Game Interactions

- Two Players are each dealt a hand of cards.
- Players take turns alternating between rounds of "attack" and "defense" (i.e., Player 1 attacks while Player 2 defends, and vice-versa).
- Arithmetic is used throughout game play to measure the effectiveness of each "attack" and "defense."*

An Attack Example

The even number card is played, along with two number cards (5 and 7), the sum of which is equal to 12 (an even number).



A student would perform the calculation 7 + 5 for an attack value of 12.

A Defense Example

The perimeter of an octagon card is played, along with the number 5. Because an octagon has 8 sides, if each side was 5 perimeter and subsequent "defense value" would be 40.

A student would perform the calculation $8 \times n$,
if $n = 5$ then $8 \times 5 = 40$.

*It should be noted that because of the turn-based nature of the game, speed of calculation plays no role at all. Furthermore, a student could rely on the distributed knowledge of the group to check the accuracy of an answer. Thus, not knowing 5 × 6 would not be a problem, so long as one could learn the correct answer from one's opponent.

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