The interplay of chance and skill: Exploiting a common game mechanic to enhance learning and persistence

Abstract: Students often display incredible persistence while playing games, despite frequent failure. This work explores whether the interplay of chance and skill, often found in games, could enhance persistence after failure in a learning environment. This study contrasted two conditions in the context of an educational game about genetics. In the Skill-Only condition, students were told that winning in the game was deterministic and based solely on skill. In the Chance+Skill condition, students were told that winning in the game was probabilistic, based on a combination of chance and skill. In the Skill-Only condition, students tended to persist when they experienced success and gave up when they failed, and low-failing students made greater learning gains than high failers. The Chance+Skill condition had an equalizing effect that eliminated the negative effects of failure on both persistence and learning. Infusing a learning environment with this game-like mechanic benefited both motivation and learning.

Introduction
Students encounter many learning failures in their school careers. When doing a math problem, coming up with an idea for an essay, or writing a computer program, students’ first attempts often fail. To learn from these failure situations students must persist and learn from their mistakes. But rebounding from failure is non-trivial. It requires a sophisticated set of motivational behaviors that many novices, including children, do not perform (Chase, in press). At the same time, there are specific contexts where children show exceptional perseverance in the face of setbacks. One of these contexts is a game. Often the child who quickly gives up on understanding multi-digit division will spend hours mastering the supreme boss level of World of Warcraft. This research explores the potential of games to help students persist in the face of short-term failure, with the ultimate goal of enhancing learning. In particular, this study investigates the chance element incorporated in many games as a potential motivator in the face of failure.

Games are intensely motivating for many children. As of 2003, 92% of all children between the ages of 2 and 17 play video games an average of 20-33 minutes per night (Kaiser Family Foundation, 2003). Adolescents play far more than this, with girls clocking in at 5 hours per week and boys at 13 hours per week on average (Gentile et al., 2004). Moreover, on a survey of online role-playing games, over half of adolescent players said they found games “addictive” (Yee, 2006). Video game sales statistics confirm these observations; worldwide sales reached $32 billion in 2008 (Video Business Online, 2009). These numbers demonstrate that games are highly engaging for children and they are here to stay.

The question is whether we can harness the motivational power of games to facilitate academic learning. Much of the research on gaming motivation has focused on the attributes of games that make them intrinsically motivating or enjoyable in their own right, such as challenge, fantasy, and curiosity (Ryan, Rigby, & Przybylski, 2006; Lepper & Malone, 1987). More recent work has examined the broader social networks around gaming and their draw as a space for social interaction (Ducheneaut, Moore, & Nickell, 2007). The work presented here focuses on another aspect of games that could induce positive motivational behaviors: a combination of chance and skill.

The outcomes of many games are dependent on a blend of chance and skill. For instance, performance in the game “go fish” is dependent upon the cards one happens to fish as well as the strategy one employs in handling them. Successful games often contain outcomes that are elegantly controlled by a combination of chance and skill. Many of these games, such as black jack or poker, can be highly addictive, and people continue to play them despite frequent experiences of failure. In fact, chance is a crucial part of game design. For instance, in Salen and Zimmerman’s influential book on game design, The Rules of Play (2003), they devote an entire chapter to “games as systems of uncertainty” which explores the interplay of skill and chance elements in a game, with the goal of producing a game that players will want to keep playing.

Given the motivational power of games, chance shows promise as a tool for promoting persistence after failure. This is at odds with most standard achievement outcomes, which are based solely on the student’s skill or knowledge. In addition, a large body of motivational research in achievement contexts has shown that encouraging students to attribute failure outcomes to uncontrollable causes (like chance) can hinder subsequent effort and persistence and ultimately hurt performance (Stipek & Weisz, 1981). For instance, the phenomenon of learned helplessness, where individuals do nothing to avoid an aversive outcome, occurs when they perceive no relationship between their behavior and the negative event, rendering the outcome uncontrollable (Seligman & Maier, 1967).
study by Diener and Dweck (1978) compared helpless and mastery children’s response to failure at discrimination problems. The helpless children attributed failure to uncontrollable factors like lack of ability or task difficulty, used less effectual strategies, and engaged in fewer self-monitoring behaviors. In response to this work, many researchers advocate that students should be taught to attribute poor performance to internal, controllable factors, like effort, which place the responsibility for remedying the failure on the student’s own hard work (Schunk, Pintrich, & Meece, 2008).

From the perspective of motivation research in the realm of academic achievement, providing students with chance as a possible cause of academic outcomes should deter persistence. However, there are several reasons to believe that adding an element of chance could encourage persistence, particularly in response to failure. First, one of the major impediments to persistence is avoidance of the negative ramifications of failure. The experience of failure is associated with negative emotion, lowered self-esteem, reduced intrinsic motivation, and lower expectancies of future success, particularly when the failure is attributed to internal causes (Covington & Omelich, 1981; Reeve, Olson, & Cole, 1985; Vallerand, Gauvin & Halliwell, 1986). A common self-protective response to failure is to quit the task entirely, avoiding the risk of future failure and all its negative consequences. Blaming failure on external causes, like chance, may act as an ego-protective buffer, protecting one’s sense of competence and reducing avoidant behaviors like quitting (Chase, in press). Second, persistence at chance-influenced tasks could be enabled by the gambler’s fallacy. The gambler’s fallacy is an erroneous belief that a string of similar outcomes is most likely followed by a different outcome (for a review, see Lee, 1971, Ch. 6). For instance, gamblers often believe that they are more likely to win after a streak of losses, even though each gambling outcome is independent from the next. When translated into the context of an educational game, the gambler’s fallacy may lead students to persist at a learning task, despite frequent failure, by raising their expectancy of future success. However, in the context of an educational game this may not be an actual fallacy, since more game play could lead to greater learning, which in turn could increase the odds of future success. Third, chance-influenced outcomes may give people hope that they can still succeed after failing (Snyder, 1994). Students may continue to play a challenging educational game because there is always a chance they could win.

Perhaps games with combined chance-skill situations have found the magic formula for motivating persistence by taking the best of both worlds. Skill-based activities motivate students to take responsibility for outcomes and put in the personal effort to remedy failures and achieve success. Chance-based activities provide students with ego-protective mechanisms for averting the blame for failure away from the self. In addition, the gambler’s fallacy and hope could increase the expectancy of future success. Infusing learning outcomes, which are typically based on skill alone (e.g. test performance), with a bit of chance could have a positive effect on persistence after failure. This might create a motivational sweet spot where students are driven to take a chance after failure by putting in the the effort to remedy the failure.

The current work explores the possibility of injecting a learning environment with game-like attributes (such as outcomes that are predicated on both chance and skill) to promote persistence at challenging learning tasks. To explore this, I created an educational game to teach middle school students about genetics. In the game, students had access to multiple rounds of games on various genetics topics in addition to multiple learning resources. There were two conditions. In the Skill-Only condition, which mimics standard achievement scenarios, students were told that success and failure in the game was a deterministic outcome. To win a game round they needed to get 75% percent of answers correct. Performance in the game was solely dependent on skill. In the Chance+Skill condition, students were told success and failure in the game was a probabilistic outcome. The more questions they got right in a game round, the more likely they were to win, but there was still an element of chance involved. In this condition, students were led to believe that their performance was a function of both random chance and skill. In reality, wins in both conditions required students to get 75% correct; the only manipulation was the perceived cause of success and failure. Outcome measures included behavioral measures of persistence in the game and pre-post learning gains. I predicted that students in the Chance+Skill condition would exhibit greater persistence after failure and learn more because of this persistence.

**Methods**

**Participants**

Study participants were 153 seventh-grade students from an ethnically diverse public school in California (35% Asian, 25% Latino, 22% Filipino, 11% White, 4% African-American and 3% other; 37% qualify for free lunch programs). Participants were drawn from five different classes taught by the same science teacher. Participants were assigned to condition through random stratified sampling within class, based on science class grades and gender.
Learning Environment

The study used an educational game called Mendel’s Galaxy (see Figure 1), which was designed to teach students about patterns of genetic inheritance. The game is equipped with a variety of learning resources, to help students learn the complex genetics content. In addition to choosing learning resources, students selected both the topic(s) they wanted to learn and the sequence of those topics. To investigate persistence in the face of failure, the game contained topics of varying difficulty, to ensure a mixture of success and failure in the game. There were multiple game rounds per topic, to give students the option of trying again after losing.

Mendel’s Galaxy is built around an alien genetics narrative. Players take on the role of geneticists-for-hire who travel the galaxy, zooming from planet to planet, helping aliens unlock the secrets of their heritage by solving a series of genetics puzzles.

The game covers seven different topics including: Punnett squares, probability, prediction, family trees, codominance, Punnett squares with two genes, and family trees with two genes. Each planet has a unique type of puzzle or game that addresses a different genetics topic. There are 4 isomorphic puzzles or game rounds on each planet, to provide students with multiple chances to master a topic. Each puzzle contains a set of questions or “challenges.” The number of questions on a puzzle ranges from 4 to 10, depending on the topic. Figure 1 contains an example puzzle on the topic of family trees. Students were free to choose if and when they played each game topic; they could leave or return to a planet at any time.

The game allows for frequent experiences of success and failure. For each puzzle the players win, they are awarded 10 points or “zorks”. Each time players lose a puzzle, 1 of their “crew” is taken away. The total number of crew and points are tracked in the score box, located in the upper right hand corner of every screen (see Figure 1). Once all the crew are gone, the game is over.

Design

The study contrasted two conditions: a Skill-Only condition and a Chance+Skill condition. In the Skill-Only condition, students were told that the outcome of a puzzle was deterministic, based solely on their personal performance in the game. Winning was determined by a simple 75% rule. If more than 75% of the questions in a puzzle were answered correctly, the game was declared a win. Winning and losing in this scenario was entirely dependent on the player’s performance, or skill at solving the genetics puzzles.

In the Chance + Skill condition, students were told that the outcome of a puzzle was probabilistic; winning a game was a function of both chance and the player’s performance. The more questions students answered correctly in a game, the better their chances of winning. Figure 2 shows the page displayed to students after completing a puzzle. It shows the number of correct answers and the total number of questions (challenges). To determine the outcome of the puzzle, an alien host throws green and red balls into a bag. The number of green balls
is equal to the number of correct answers, and the number of red balls is equal to the number of incorrect answers. The alien host then shakes the bag and randomly picks one ball. If he selects a red ball, the player loses. The combination of chance and skill was meant to encourage persistence, particularly following failure. Moreover, it gives students an incentive to learn. If they were to get more questions right on the quiz, their chances of winning would improve.

<table>
<thead>
<tr>
<th>Chance + Skill condition</th>
<th>Skill condition</th>
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<tbody>
<tr>
<td>You get 4 out of 6 challenges correct. 4 green balls and 2 red balls will go into the bag.</td>
<td>You get 4 out of 6 challenges correct.</td>
</tr>
<tr>
<td>UH OH! One of your crew has been taken hostage!</td>
<td>UH OH!</td>
</tr>
<tr>
<td></td>
<td>You got &lt;= 75% correct. One of your crew has been taken hostage!</td>
</tr>
</tbody>
</table>

Figure 2. Failure message screens for Chance + Skill and Skill conditions. The Chance + Skill condition was told that the outcome of the game was probabilistic. The Skill condition was told that the outcome was deterministic.

In reality, the computer followed the 75% rule to determine wins for both groups. However, students were led to believe the cover story in their respective conditions. Cover stories were explained to students via Powerpoint presentation on the first day of game play, were reiterated on the second day of the game play, and were further reinforced by the alien host’s actions in the game.

Procedure
The study took place over the course of one full week of school, in students’ regular classroom. On the first day of the study, all students completed the pretest. Next, students played the game for two 35-minute sessions, spread out over two consecutive days. In the following week, all students took the posttest.

On the first day of game play, the experimenter explained the game narrative and game instructions to the entire treatment group with a Powerpoint presentation. Each condition received a different explanation of how to win a puzzle. Afterwards, students logged into the game on individual laptops and played for approximately 35 minutes.

On the second day of game play, the experimenter reiterated the game instructions and further explained how to win a puzzle. Again, these explanations differed depending on condition. In the Chance+Skill condition, it was explained to students, through the use of a few examples, that the likelihood of picking a green ball would increase as the proportion of correct answers rose. In the Skill-Only condition, the 75% rule was reiterated and then demonstrated on the same set of examples. After the brief explanation, students logged into the game and again played for about 35 minutes.

Measures

Pretest
The pretest contained seven items. Each item was designed to address the content from a different planet. The items were very similar to the game puzzles but used different surface features (i.e. different genetic traits and species) and were presented in word problem form (rather than the graphic presentation used in the game). Each item contained several questions using a fill-in-the-blank format. Most questions asked students to derive the correct genotype or phenotype of a potential child, given the genotype/phenotype of its parents. Other questions asked students to calculate the probability that two parents would have a child of a particular genotype. Figure 3 contains a sample test item.

Each of the seven items contained several sub-questions. Each sub-question was given a score of 1 for a correct answer and a score of 0 for an incorrect answer. Because each item contained varying numbers of sub-
questions (ranging from 2-8), scores for each item were converted to proportions (on a scale of 0-1) so that each item would be weighted equally when aggregated with other items on the test.

Posttest
The posttest contained 7 questions that were identical to the pretest questions except they differed on the surface features of species and genetic traits. Pre- and posttests were coded by three separate coders who compared students’ answers to an answer key. Given the low-inference coding scheme (i.e. answers were either right or wrong and usually consisted of numeric answers), reliability between coders was not necessary.

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Log Data
A database logged many of students’ discrete choices in the game, creating a sequential record of students’ actions. Several two-event sequences were coded in the log data to explore the relationship between failure, success, and persistence. Our main measures of persistence were “fail-abandon” and “success-abandon”. These behaviors occurred when a student either failed or succeeded and then immediately moved to a different planet, abandoning a topic.

Results
The results will first explore learning effects by condition followed by some interesting individual differences between high and low failers. Next, analyses will consider the differential effects of condition on persistence after both failure and success. Finally, the relationship between persistence and learning outcomes, across conditions and high/low failers, will be examined.

Learning Outcomes
Pretest scores were similar across conditions, demonstrating equivalent prior knowledge across the groups, $t(128) = .34, p = .74$. To test whether students learned from the game, students’ average question scores were compared from pretest to posttest. On a paired sample t-test, pre- and post-test scores differed significantly, $t(127) = 10.40, p < .001, d = .48$. On average, students’ scores increased from pre- to posttest by 10 percent, a moderate improvement.

A key hypothesis was that an element of chance would facilitate learning. To test this prediction, Chance+Skill and Skill-Only conditions were compared on average learning gains from pre- to posttest. A learning gain score was computed by finding the difference between pre and post-test scores and dividing by the square root of 1 minus the pretest score: $(Post-Pre) / \sqrt{(1-Pre)}$. This transformation gives all participants equal “room” to gain from pre to post-test while normalizing the distribution of gain scores. The effect of condition on learning gain was not significant, $t(126) = .89, p = .37$ (see Table 1), indicating that the chance manipulation did not have an overall effect on learning gains.

Table 1. Means and standard errors for pretest, posttest, and learning gains.
Learning outcomes by failure

Since the Chance+Skill manipulation was designed to promote persistence after failure, one potential hypothesis is that the chance manipulation only affected students who experienced a great deal of failure. Reciprocally, the Chance+Skill manipulation may not have benefited students who rarely failed. To test this prediction, students were binned into high and low failers based on failure rates (number of fails divided by number of games played). Categorizing people into the dichotomous categories of high and low failers provides a simple way to conceptualize the effect of failure on learning in each condition.

Groups were split on the median failure rate to ensure equal sample size in the high and low failer groups. Both the median and mean failure rates were nearly identical across conditions (MedianSkill-Only = .50, MeanSkill-Only = .52, SDSkill-Only = .29; MedianCHANCE+SKILL = .50, MeanCHANCE+SKILL = .48, SDCHANCE+SKILL = .29). On average, students failed 50% of the games they played. The distribution of failure rates was relatively normal across conditions, so there is no danger that the median split obscured the effects of a non-normal distribution.

To test whether the chance manipulation had a different effect on learning for high and low-failing students, a factorial ANOVA crossed the factors of condition by high/low failer to predict learning gain. There was no main effect of condition $F(1, 126) = .34, p = .56$, but there was a significant main effect of high- versus low-failers $F(1, 126) = 17.75, p < .001$, demonstrating a lower gain score for the high-failers. Most importantly, there was a significant interaction effect $F(1, 126) = 5.86, p = .02, d = .2$. As shown in Figure 4.1, students in the Skill-only condition who had a high rate of failure learned far less than their low-failing counterparts. However, in the Chance+Skill condition, high- and low-failers made the same learning gains, demonstrating that the students in the Chance+Skill condition seem unaffected by failure. Post-hoc comparisons using Tukey’s HSD indicated that the gain score of high- and low-failers in the Skill-only conditions differed significantly, $p < .05$, while this was not the case in the Chance+Skill group.

When removing the binning and treating failure as a continuous variable, the rate of failure had a stronger relationship with learning gains in the Skill-Only condition ($r = -.50, p < .001$) than in the Chance+Skill condition ($r = -.28, p = .03$). In the Skill-Only condition, each additional failure was associated with a larger decrement in gain score than in the Chance+Skill condition. Taken together, the results of the ANOVA and correlations indicate that failure had a stronger effect on learning in the Skill-Only condition than in the Chance+Skill condition. This fits the hypothesis that making students’ performance contingent on both chance and skill can protect them from the negative ramifications of failure that often interfere with learning. However, this protection is most effective for students who experience high rates of failure.

Persistence after success and failure

Could these differences in learning outcomes be explained by differing levels of persistence in the game? Another main hypothesis was that the Chance+Skill manipulation would discourage the behavior of abandoning after failing a round of the game. To test this prediction, the rate at which students abandoned a topic after failure was compared
to the rate of abandonment after success in both conditions. The rate of fail-abandon was computed by dividing the total number of abandonments after failure by the total number of failures in the game (summed across both days of game play). Dividing by the number of fails ensures that any effects are due to abandonment rather than failure per se. To compute the success-abandon rate, the number of abandonments after success was divided by the total number of successes. Rates of success-abandon and fail-abandon create a simple within-subjects comparison that controls for the effect of overall rate of abandonment, regardless of failure.

To test the effect of condition on abandonment after success and failure, a repeated measures ANOVA crossed the between-subjects factor of condition by the within-subjects factor of success-abandon vs. fail-abandon. There was no effect of condition, $F(1,129) = .11, p = .74$. However, there was a significant interaction of condition by success- vs. fail-abandon, $F(1,129) = 6.00, p = .02, d = .2$. There was a marginal main effect of success- vs. fail-abandon, $F(1,129) = 3.07, p = .08$, though this effect appears to be driven by the interaction. As shown in Figure 4.2, and confirmed by Tukey’s post hoc tests, the Chance+Skill students were equally likely to abandon after a success or failure, while the Skill-Only students were far more likely to abandon after failure than after success, $p < .05$. By this analysis, the hypothesis that the Skill-only condition would fail-abandon more was partially confirmed. While the Skill-Only students did not fail-abandon at a significantly higher rate than the Chance+Skill group, the Skill-Only students’ rate of fail-abandon was far higher than their own rate of success-abandon. So, the introduction of a chance element did not reduce the incidence of fail-abandon. Rather, it equalized the likelihood of abandonment after success and failure. One interpretation of this result is that the Skill-Only students abandoned a topic when they failed and stuck with it when they succeeded. Relative to the Skill-Only group, the Chance+Skill group was more persistent after failure and more willing to take a risk by leaving a game topic when they succeeded. Another interpretation is that failure and success did not affect persistence in the Chance+Skill group. The Chance+Skill students were less reactive to the outcomes of the game.

Did persistence behaviors relate to learning? To examine the effect of fail-abandon and success-abandon on learning, simple correlations with the gain scores were computed for the full sample and for each condition (see Table 2). There were no significant correlations between success-abandon and learning. However, there was a significant negative correlation between fail-abandon and learning in the full sample. When broken out by condition, both Skill-Only and Chance+Skill groups showed small, negative, non-significant correlations between fail-abandon and learning gains. These results indicate that the more students abandoned after failure, the less they learned from the game, regardless of condition. This is a rather weak effect, but nonetheless it shows that persistence after failure did have an impact on learning.

### Table 2 Correlations between learning gains and rates of success- and fail-abandon.

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Skill-Only</th>
<th>Chance+Skill</th>
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<tbody>
<tr>
<td>Success-abandon</td>
<td>-.05</td>
<td>-.06</td>
<td>-.08</td>
</tr>
<tr>
<td>Fail-abandon</td>
<td>-.18*</td>
<td>-.14</td>
<td>-.23</td>
</tr>
</tbody>
</table>

* significant at $p < .05$

Did these effects on persistence differ across high and low failers in each condition? A three-way ANOVA did not find condition differences in high and low failers’ rates of fail-abandon and success-abandon ($F(1, 220) = 2.6, p = .32$). Nor did the association between fail-abandon rates and learning outcomes differ significantly for high and low failers in each condition. Given these findings, the relationship between persistence after failure and the differential learning outcomes between high and low failers across conditions is unclear.

### Discussion

Combined chance and skill outcomes equalized learning across high and low failers, by bringing high failers to the same level as their low-failing counterparts. Likewise, students in this condition showed a dampening effect on their behavioral response to failure. Chance+Skill students were equally likely to persist after success and failure. Whereas, Skill-only students were less likely to persist after failure and were more likely to “play it safe” by continuously playing easy games (where they experienced success). While persistence after failure (as measured by fail-abandon) is related to learning, its connection to high and low-failing students’ learning is unclear. Nonetheless, a blend of chance and skill shows promise as an effective tool for promoting persistence in environments where the risk of failure is high.

An interesting question raised by this study is whether the Chance+Skill manipulation influenced productive persistence in response to failure. In other words, were students more or less likely to check a relevant learning resource (e.g. reading or elaborate explanations) when outcomes were partially due to chance? Though
these data were not presented in the results section, the results show that the Chance+Skill manipulation had no effect on productive persistence. Future research might explore adding metacognitive tips to encourage students to engage the more productive learning resources after failure.

What recommendations can this research make for classroom practice? To suggest that teachers should tell students their performance is based on a mixture of skill and chance would be unfounded. More research is necessary before strong conclusions can be drawn. However, the overarching message of this work is that games can offer novel suggestions for improving motivation in classrooms, ones that may not be supported by the traditional research on motivation in achievement contexts.

Endnotes

1 In cases where post-test scores were lower than pretest scores, the difference from pre- to post-test was divided by the pretest score, to compute the percent “lost” from pre to posttest. In cases where there was no change from pre- to post-test, the gain score was set to 0.

References


