NYINGI: OFFICIAL GAME DESIGN DOCUMENT

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Proposal number: 1
NYINGI IN A NUTSHELL

Players choose a board from the board pile based on difficulty. Each player is dealt 7 cards with the remaining ones placed face down to form a draw deck. The player to the left of the dealer goes first, with the winner of each round getting to start first after the first round.

In order for one to claim a spot/number on the game board, one must put down three cards that when multiplied together result in that number. For example, if a player wants to claim a spot numbered 36 they can put down a 4 card, a 1 card, and a 9 card (4 x 1 x 9 = 36). Once all other players have confirmed that they player has made a correct play, they can put their game piece on the board. Once a player has played three cards, they pick up three cards from the top of the draw deck and put the three cards they played at the bottom of the draw pile.

The only time a player can play just one card is when they have a prime card and use that prime card to claim prime number on the board. Prime cards can also be combined with two other cards to claim a spot. For example if a player wants to claim a spot numbered 84 they could play a 2 card, a 6 card, and a prime card. Before claiming the spot, the players must announce what prime number the prime card represents, in this case a 7. If the player incorrectly states a prime number, they lose their turn, must pick back up their cards, and must pick a card from the draw deck.

Wild cards are similar to prime cards in that they can be combined with two other cards, with the only difference being the wild card can represent any number. For example if the player wants to claim a spot numbered 100 they can put down a 10 card, a 2 card, and wild card. As with the prime card the player must announce what number the wild card represents before claiming the spot. If they are incorrect they must pick up their cards, pick a card from the deck and lose their turn.

If at any moment a player doesn’t have a play, they have one of two options:

1. Pick a card from the top of the draw deck and lose their turn.
2. Trade up to three cards from their hand, with three cards from the top of the draw deck, and lose their turn.

If a player is taking too long to play, then anyone can call a time challenge. The player whose turn it is now has 20 seconds to play or lose their turn.

CHOOSING A DEALER

Each player picks a card. The player who picks the highest number deals. If you picked a "word" card, too bad, they don't count. Player to the left of the dealer starts play.
VARIATIONS

**Keep Score:** When a player is out of cards, he gets points for cards left in the opponent's hands as follows:
- All cards through 10 Face value
- Wild = 10 points
- Prime Card = 20 points

The WINNER is the first player to reach 500 points. However, the game may be scored by keeping a running total of points of each player is caught with at the end of each hand. When one player reaches 500 points, the player with the lowest points is the winner.

**Partner Play:** With four players, play four hands with each of the other three players as your partner (a total of 12 hands). Each player keeps track of his points scored in each partnership. Play several rounds, with the person scoring the highest number of points declared the winner. With eight players, play two separate games at two tables, with each player having every other player as a partner for four hands each (a total of 28 hands). Score as above.

**Do It Yourself** - Instead of using one of the boards, create your own board using the blank board and dry erase marker.

**2 or 3 Card Play** - Instead of having to play three cards, you can play two cards. Once you have played you only pick the number of cards that you have put down.

**Unlimited Card Play** - You can put down as many cards as want to make a legitimate play. Once you have played you only pick the number of cards that you have put down.

**Distributed Card Play** - You can only put down three cards, but two of the cards must be added together and then multiplied by another card in order to claim a numbered spot (or vice versa). For example if you want to claim a spot numbered 25 you can put down a 3 card, a 2 card, and 5 card. They player must state the two cards that are being added together and they number that is being multiplied together in order to claim the spot. In this example the player would say “3 + 2 x 5” or “5 x 3 + 2”

\[(3 + 2) \times 5 = 5 \times 5 = 25\]

\[5 \times (3 + 2) = 5 \times 5 = 25\]

If the player is incorrect, they must pick up their three cards, pick a card from the draw deck, and lose their turn.

**Time Crunch** - Play using the original rules of the game or one of the variations but this time each player has 10-15 seconds to play or lose a turn.
Wild Cards

3x3 = 9
2x5 = 10

Size of C=8

Place, pull 7, rolls 7 cards

Each player pulls 7 cards

Time to draw, 4 chips per row or col.

Blows for 4

All upfold values doubled

Place 5 of each Wild Cards

Play until

Redshelve 2

Play cards run out

From deck

Player card

# of cards

63
54
35
91
21
17
12
50
18
14
59

Players

Has to set

1 of 2

Redshelf 2

2

Players

Remove piece

2

Place turn

Pull 3

Pull 4
Improving the Design of a Learning Game Through Intrinsic Integration and Playtesting

André R. Denham

Abstract Designing and developing games for learning is a difficult endeavor. Educational game designers must not only make an engaging and motivating game, but must also ensure that learning takes place as a result of gameplay. Educational researchers have sought to define design principles in order to lessen the difficulty involved with game design. In spite of these efforts, there is still a paucity of empirical research in support of significant direct learning gains that result from time spent in a game environment. This study investigated the effectiveness of a design and development approach centered on playtesting, with the purpose of ensuring the proper intrinsic integration of multiplication properties, concepts, and strategies within the game’s mechanics.

Keywords Game-based learning · Game design · Playtesting · Mathematics

1 Introduction

Educational researchers, theorists, and practitioners are interested in the use of games for a variety of reasons, most of which are related to the inherent characteristics of games. In general, games are goal-oriented, engaging, motivating, provide continuous feedback on performance, require participants to think critically, allow participants control over the environment, and are excellent at creating endogenous value (Wong 1996; Gee 2004; Prensky 2005; Shaffer 2006; Tobias and Fletcher 2011; Nelson et al. 2005; Barab et al. 2007; Squire and Klopfer 2007; Shute and Ke 2012, etc.). These characteristics are representative of an ideal learning environment (Devlin 2011).

That being said, not all educational games are good games (Gee 2005; Van Eck 2006). Many attempts at creating educational games result in failure or inconclusive findings.
Two factors contribute to this. First, educators directly involved in the creation of games for learning may not be skilled game designers. The games an educator would create are more likely to be pedagogically sound educational technology, but may also lack the elements needed to make an engaging and motivating game (Van Eck 2006). Second, experienced game designers are capable of creating rich, immersive game environments, which encourage hours of gameplay. What commercial game designers may lack is an awareness of pedagogy, learning theory and/or how to develop games that assist players in achieving instructional objectives while still remaining enjoyable and replayable (Van Eck 2006).

One point of continual discussion within the games-for-learning community is how to address these issues. The argument often centers on design principles, such as whether games should meet instructional objectives through endogenous (intrinsic) or exogenous (extrinsic) gameplay. Malone (1981) first tackled this issue by developing a theory that instructional games should account for the following motivational heuristics when being designed: challenge, fantasy, and curiosity. Malone and Lepper (1987) expanded Malone’s earlier theory on heuristics for designing instructional games by adding four motivations: control, cooperation, competition, and recognition. Within this expanded taxonomy of intrinsic motivations for learning in games, Malone and Lepper distinguished between endogenous and exogenous games by defining endogenous games as games that have the following properties (Malone and Lepper 1987, p. 240):

1. “The skill being learned and the fantasy depend on each other.”
2. “There is an integral and continuing relationship between the fantasy context and the instructional content being presented.”

Malone and Lepper defined an exogenous game as “one which the fantasy depends on the skill being learned but not vice versa” (Malone and Lepper 1987, p. 240). In other words, the instructional content being taught is outside, or exogenous, to the actual game being played. Habgood et al., (2005) review of intrinsic learning in games provided an excellent example of an exogenous game: Hangman. Success in Hangman depends on the player’s knowledge of spelling and vocabulary, but that could easily switch to knowledge of mathematics if desired. The game mechanics remain the same, as they are independent of the instructional content. Based on these two definitions and several empirical studies conducted to support the use of these design principles, Malone and Lepper contended that, “in general, endogenous fantasies are both more interesting and more educational than exogenous fantasies.” (Malone and Lepper 1987, p. 240).

Habgood et al. (2005) provided an alternative theory to Malone and Lepper’s taxonomy for learning through endogenous digital games. They contended the term “endogenous fantasy” is limiting in its scope, and learning gains would be better accomplished through what Kafai (2001) called intrinsic integration. Habgood, Ainsworth, and Benford characterized intrinsic integration as having three distinct traits: Flow, core mechanics, and representations. Flow, “a feeling of total concentration, distorted sense of time, and extension of self” are feelings identifiable by anyone completely engaged on a task (Habgood et al. 2005, p. 492). Core mechanics are the “mechanism through which players make meaningful choices and arrive at a meaningful play experience” (Salen and Zimmerman 2003, p. 317). Habgood et al. believed core mechanics are important for intrinsic integration because they help to create activities within the game relevant to the player. Core mechanics also help to create flow experiences and assist in channeling many motivating by-products such as “challenge, control, cooperation, and competition” (Habgood et al. 2005, p. 493). Finally, the authors presented representations as the final
core trait of intrinsic integration and point to empirical research which supports the sup-
position that the structures and interactions within an educational game will be more
beneficial for learning if the representations are metaphors of the learning content (Ains-
worth and Loizou 2003; Miller et al. 1999; Papert and Talcott 1997; Reiber 1996). By
weaving interactions within the game with the metaphoric representations of the learning
content, players will develop deeper conceptual understanding of the instructional content
(Martin and Schwartz 2005).

Habgood conducted several empirical investigations in an attempt to determine the
effectiveness of applying intrinsic integration strategies to the design and development of
an educational game. Habgood and Ainsworth (2011) developed Zombie Division, a game
created to teach whole-number division, and conducted an investigation in which three
versions of the game were tested for player enjoyment and ability to support learning. In an
empirical study, Habgood and Ainsworth found those who played the intrinsic integration
version of Zombie Division significantly outperformed all other conditions on measures of
learning and engagement (Habgood and Ainsworth 2011). Additionally, those who played
the intrinsically designed version of the game maintained their significant learning gains on
a delayed posttest. Denham (2013), found similar findings when reporting on a game
designed to teach multiplicative properties and support automaticity of multiplication facts.
Those who played the intrinsically designed version of the game had significantly higher
learning gains than those who did not and were on average significantly more likely to
want to continue playing their version of the game when compared to those in the other
conditions.

Intrinsic integration shows promise, but applying this design principle may not be
enough to design a good learning game. Those in the business of educational game design
must also include playtesting as a fundamental component of the design process (Becker
and Parker 2014; Fay 2014). Playtesting is important because it helps determine whether
the target audience finds the game engaging and replayable. No matter how pedagogically
sound a game is, if the target audience does not enjoy it, then the instructional objectives
will receive no attention.

Those in the business of commercial game development consider playtesting to be of
the utmost importance, based on their understanding that “playtesting allows developers
to understand how players will experience their game, leading to increased fun, sales,
and a higher quality final product” (Fay 2014, p. 256). So the question for educational
game designers should not be if we should playtest our games, but how to playtest our
games.

Inherent to playtesting is the idea of iterative refinement. During the iterative refinement
process, changes to the game are made based on playtesting sessions in which the goal is
“to find out whether the game is fun to play, what parts are not fun, what parts are hard or
confusing, and whether the players are generally pleased with the result” (Becker and
Parker 2014, p. 194). While playtesting should not aim to collect statistically significant
data, playtesting sessions can provide anecdotal evidence of whether learning occurs (Fay
2014). This information can help refine subsequent iterations of the game and allow for
educational designers to complete as many “design-build-test” cycles as possible. This
may require that analog versions of the game be built prior to making a digital version, but
in the end will result in a higher quality product and increased potential for the creation of a
game that is engaging, immersive, replayable, and educational.

This study sought to contribute to the work being done on game-based learning design
principles by examining the impact of intrinsic integration, playtesting, and iterative
refinement, prior to the collection of learning data. The combination of all three elements
should result in a game design process that helps to achieve the gold standard of high levels of engagement, motivation, and learning from playing an educational game. This manuscript reports on the design process, playtesting sessions, refinements, and subsequent quasi-experimental study that led to the refinement of Nyingi, a game designed to teach multiplicative conceptual understanding.

1.1 Nyingi

Nyingi, is a two-to-four player board game that is a combination of Tic-Tac-Toe, Bingo, and Uno. Nyingi is a Swahili word meaning “excessive.” The game was given this name after the playtesting sessions, during which a large variety of applications for the game emerged. The initial version of the game had the goal of winning by claiming a diagonal, horizontal, or vertical row of numbered spots on the board.

In order to claim a spot/number on the game board, the player must play three cards that, when multiplied together, result in that number. For example, if a player wants to claim a spot numbered 32, they can put down a 2 card, a 2 card, and an 8 card \((2 \times 2 \times 8 = 32)\). The reasoning behind having players put down three cards instead of two cards is to have them think about multiplication as more than just fact pairs. Additionally, the playing of three cards mimics the associative property of multiplication \([which is (a \times b) \times c = a \times (b \times c)]\). Each player starts with seven cards, with a draw pile of leftover cards. Once a player claims a number on the game board they pick three cards from the top of the draw pile, so that they always have seven cards in their hands (Fig. 1).

Version 1.0 of Nyingi consisted of game boards of varying size \((3 \times 3, 4 \times 4, 5 \times 5, \text{and } 6 \times 6)\), a deck of cards, and game pieces for users to mark the spots they claimed on the board (see Fig. 2).

1.2 Methodology for Playtesting Sessions

A combination of Fullerton et al. (2004) and Fay’s (2014) playtesting and iterative game design methodologies informed the playtesting portion of Nyingi’s design. This section describes the rationale for using and combining these methodological approaches. The goal of the playtesting sessions are presented, followed by a more detailed discussion of each session, which will include an explicit description of playtesting procedures, data sources, and methods for data analysis.

![Fig. 1 Gameplay example](image-url)
2 Playtesting Models

Fullerton, Swain, and Hoffman considered playtesting the most critical task a game designer could engage in. Playtesting is more than the game design team playing the game in order to discuss game mechanics or to bug test software. Instead playtesting is an integral element of the game design process, conducted either informally or formally, through qualitative, quantitative, or mixed-methods. Fullerton, Swain, and Hoffman’s model for iterative game design recommended testing and revising a game from the concept phase to the launch of the game (see Fig. 3).

Much of Fay’s methodology and rationale for conducting playtesting mirrored that of the aforementioned model. The main difference between the two models is the intent. The previously discussed model focuses on building good games, while Fay’s model uses
playtesting to create good learning games. This requires the added dimension of collecting learning data during playtesting in order to determine whether or not players are in fact learning, as well as the level to which they either transfer or retain what they have learned. Fay’s model places an emphasis on the collection of learning data once the designer is satisfied with the design of the game in terms of playability. The rationale for this approach depends on the fact that players are more likely to learn and retain information if they are engaged and motivated during gameplay. In other words, what good is a learning game if no one wants to play it more than once? Figure 4 provides a combined model for the iterative design of learning games.

Applying this model for playtesting is beneficial for a variety of reasons. Firstly it provides the design team with a structured means of gathering insights into the design of the game that would not have emerged by any other means. Secondly this method allows for multiple playtesting sessions by reducing the focus on conducting a rigorous, tightly designed scientific assessment during the development cycle. This allows the design team to focus on improving the game with the intent of assessing learning effectiveness once they feel confident about the robustness of their product. This is not to say the methods employed in this model lack rigor. Instead the proposed model provides a path to increase the likelihood of making a good learning game that is also engaging and motivating. Finally, playtesting throughout the development cycle, as opposed to waiting for a beta version, lessens the cost associated with making significant changes to the game.

This approach to playtesting requires the collection of a variety of data in order to make design decisions. The data sources required to conduct playtesting are observational data collected during playtesting (e.g., choices made, points of confusion, excitement, players’ actions, etc.), responses from facilitated and open discussions conducted after play, and learning measures. Question created before each session should guide observational data collections and analyses to help illuminate possible trends and to answer design questions.

![Model for iterative learning game design](image)

**Fig. 4** Model for iterative learning game design
The discussions that take place after gameplay should be semi-structured, with questions prepared beforehand and testers able to freely share their thoughts on the game. Finally, use a learning measure to ensure learning occurs and is a direct result of time spent playing the game.

The design team facilitated a series of playtesting sessions using this model. The first playtesting session had the express goal of determining the utility of the card deck, gaining insights on needed refinements to game rules and/or mechanics, gathering the testers thoughts on the game, and determining what improvements designers could make to the game. The second playtesting session sought to gather feedback on a new set of game rules and changes to game mechanics prompted by feedback from the first session. The third and final playtesting session focused on testing variations of the game board, as a means of varying the difficulty level of the game. This session also focused on determining if players felt they were learning anything, and if so, what they felt they learned.

3 Playtesting Session One

The first playtesting session had several questions geared toward informing the iterative refinement of Nyingi. The game design team developed these questions as a framework for the moderator to guide the playtesting session and to assist in the collection of observational data. These questions were:

1. What is the best composition of the card deck?
2. What game rules are in need of refinement?
3. Do testers feel the game is fun and replayable?
4. What suggestions do testers have for improving the game?

3.1 Methods

3.1.1 Participants

Twelve fifth graders enrolled at small private school in the southeast United States participated in this session. Fifth grade is an ideal age and grade to use for playtesting, as these students would be more likely than younger learners to have memorized multiplication fact pairs to the level of automaticity because the memorization of multiplication facts typically begins in the third grade, and is reinforced in the fourth and fifth grades (Common Core State Standards Initiative 2010). Empirical data collected on mean retrieval times of multiplication facts confirms that on average, fifth graders have faster retrieval times than those in lower grades. (Koshmider and Ashcraft 1991; Lemaire et al. 1994; Ashcraft and Christy 1995).

3.1.2 Procedure

During this initial playtesting session, the playtesting moderator’s role was to initiate gameplay, clarify game rules, and collect observational data of the players’ experience with the game. It is difficult for a moderator to observe all aspects of the players’ experience playing the game, so the moderator focused particular attention on tracking players’ interactions with the card deck and how the rules impacted game mechanics. The
moderator spent the majority of the time silently observing gameplay and occasionally asked players what they were thinking at a particular moment. Additionally the moderator could intervene if players became stuck and/or needed clarification on the rules. The playtesting session was also videotaped to allow for the design team to collect observational data that the moderator might have missed.

At the end of the playtesting session, the moderator led a semi-structured focus group to collect insights from the participants on their experience playing the game, ways to improve the game, suggestions for modifying game mechanics, if they found the game fun, and considered it replayable.

3.1.3 Data Sources

1. Moderator notes
2. Videotaped gameplay session

3.1.4 Results and Discussion

The focus on the first playtesting session was on the initial untested design of Nyingi. The first question addressed in this session was the composition of the cards in the deck. Designers wanted to know how big to make the deck, what cards to include in the deck, and distribution of cards in the deck to ensure easy gameplay. The first deck of cards had one hundred and ten cards, labeled zero through ten, with each number having ten cards. The first playtesting session revealed that the card deck was not conducive to gameplay and was in fact too large. Players complained of having too many useless cards in their hands. Players also pointed out that the zero cards in the deck had limited utility and actually served as a hindrance to the successful claiming of a spot on the board, especially if a player had multiple zeros in their hand. As one tester said, “There seems to be no chance for me to get the cards I need to claim a spot on the board”.

In terms of game mechanics and rules, several issues became evident during the session. No one was able to win a round by claiming a horizontal, vertical, or diagonal row of numbers, as players blocked any attempt to do so. This highlighted the need to provide an alternate means of winning the game. The moderator made the decision to award a win to the player who claimed the most spots on the board. This rule change within the session resulted in an immediate change in strategy by players. Players initially tried to win by claiming a horizontal, vertical, or diagonal row of numbers but when their attempts were thwarted, they would focus on claiming the most spots on the board. The moderator also observed a decrease in the time required to complete a round in the game after adding the ability to win by claiming the most spots/numbers.

Testers voiced their displeasure of having no recourse when the cards in their hand did not allow them to claim a number on the board. The moderator made the decision to modify the rules during the playtesting session to allow players to trade up to three cards in their hands with cards from the top of the draw pile. Testers suggested choosing to swap out cards should result in the loss of a turn and instead of trading cards a player could pass as well. Finally, players complained about other players taking too long to play, so a time limit of 1 min per turn was instituted.

In the focus group portion of the session, the moderator asked players to share their general thoughts on the game. Overall the testers found the game enjoyable and said they would play the game again with refinements to the game rules. One tester expressed
enjoyment from playing the game because “it was a twist on classic games”. Another tester’s enjoyment stemmed from the fact that “you had to use your brain. You couldn’t just say 2, 4, 6. You had to use combinations”. When asked what they disliked about the game, testers agreed with one tester who disliked “that once you get later into the game… it was like… you had to keep switching out cards to get cards to play”. During this discussion of the game, players echoed many of the comments mentioned during the testing session. The testers were unanimous in their desire to play the game again at some point, and many of the testers mentioned wanting a copy of the game for their classroom.

The difficulties created by the composition of the card deck, the inability of players to win by claiming a horizontal, vertical, or diagonal row of numbers, along with several other issues with game mechanics provided the design team with several areas for improvement. The insights gathered from the playtesting session highlighted the value of using this design model. Most promising was the unanimous agreement among the testers in terms of their willingness to replay the game. This inspired confidence in the design team to continue refining Nyingi in preparation for future playtesting.

4 Playtesting Session Two

After receiving feedback and observing the effect the previous version of the card deck had on gameplay during the first playtesting session, designers decided to reduce the size of the deck, remove zeroes, and to not make a uniform distribution of each number in the deck. A detailed analysis of the prime factorization of numbers between one and one hundred pointed the design team in the direction of having more ones, twos, and threes in the deck than eights, nines and tens. To allow players to claim numbers greater than ten, reduce the size of the game deck, and allow for more flexibility during gameplay, the design team introduced two new cards into the deck: primes and wilds (Fig. 5).

Prime cards could represent any prime number, and can claim a prime number on the board without the use of any additional cards (see Fig. 6).

When a player uses a prime card in combination with two other cards, the player has to state what number the prime card represents (see Fig. 7).

Wild cards, on the other hand, can represent any number. Similar to prime cards, when a player uses a wild card in combination with two other cards, the player must state what the wild card represents. Unlike a prime card, players cannot use a wild card alone to claim a spot on the board. A wild and a prime may be used in combination with another card to

**Fig. 5** Prime and wild cards
claim a spot, provided the player correctly identifies the actual numbers the prime and wild card represent (see Figs. 8, 9). A player can also combine wild and prime cards in order to claim a spot on the board.

With the inclusion of wild and prime cards and the removal of zeros from the deck, the distribution of the cards in the second version of the deck was as follows:

<table>
<thead>
<tr>
<th>Cards</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 One cards</td>
<td>blue</td>
</tr>
<tr>
<td>8 Two cards</td>
<td>green</td>
</tr>
<tr>
<td>5 Three cards</td>
<td>red</td>
</tr>
<tr>
<td>3 Four cards</td>
<td>yellow</td>
</tr>
<tr>
<td>3 Five cards</td>
<td>orange</td>
</tr>
<tr>
<td>3 Six cards</td>
<td>purple</td>
</tr>
<tr>
<td>2 Seven cards</td>
<td>pink</td>
</tr>
<tr>
<td>2 Eight cards</td>
<td>black</td>
</tr>
<tr>
<td>2 Nine cards</td>
<td>indigo</td>
</tr>
<tr>
<td>2 Ten cards</td>
<td>crimson</td>
</tr>
<tr>
<td>8 Prime cards</td>
<td></td>
</tr>
<tr>
<td>8 Wild cards</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6 Example of using a single prime card to claim a spot

Fig. 7 Example of using a prime card in combination to claim a spot

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<td>red</td>
</tr>
<tr>
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<td>yellow</td>
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<td>orange</td>
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</tr>
<tr>
<td>8 Prime cards</td>
<td></td>
</tr>
<tr>
<td>8 Wild cards</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8 Example of using a wild card to claim a spot

Springer
The reduction of the card deck and the introduction of prime and wild cards required the creation of several new rules to the game. With the inclusion of the wild and prime cards, the design team felt the need to include a check-and-balance system that would eliminate the ability of players to abuse the use of these cards. One new rule resulted in the loss of a turn if a player incorrectly stated the value of a prime and/or wild card when attempting to claim a space. In addition to the rules concerning wild and prime cards, the design team made several rule changes and introduced new game mechanics, based on feedback from the first testing session:

- If a player has no cards in their hand that can combine to claim a spot on the board, they are allowed to either pass or swap out up to three cards from their hand with the top three cards from the deck. Swapping cards out also results in a loss of turn.
- Players can win either by claiming a horizontal, vertical, or diagonal row of numbers or by claiming the most spots on the board.
- Players have 1 min per turn. After a minute the player must either pass or swap cards.

Based on the many changes made to Nyingi after the first playtesting session, the following goals (constructed as questions to be answered based on the data collected) guided the second playtesting session:

1. What effect did the reduced card deck have on gameplay?
2. Are the game rules and/or mechanics in need of further refining?
3. Do players find this version of the game more fun than the previous version?

### 4.1 Methods

#### 4.1.1 Participants

The same twelve fifth graders from the first session participated in this playtesting session. The design team felt the feedback on changes to game mechanics would be more robust by having the same group play both versions of the game and allow the moderator more time to focus on collection observational data from gameplay based on the testers familiarity with the basic game mechanics of Nyingi.

#### 4.1.2 Procedure and Data Sources

The same research procedures and data sources from the first testing session were used in this session. The only differences were that the moderator introduced the prime and wilds...
cards by providing examples of how they could be used to claim spots on the board and demonstrated the new rule changes and game mechanics through a round of gameplay.

4.1.3 Results and Discussion

The changes to the card deck had a profound effect on gameplay. Testers commented frequently through the playtesting session that they found gameplay to be smoother than the first version. The moderator also observed that testers were able to complete more rounds than during the first session. Testers responded positively to the inclusion of prime and wild cards, with one commenting, “I liked that there were wild and prime cards so it wasn’t just numbers, and... um it was kinda like chance because you didn’t know what cards you were going to get”. One issue arose during this session and it occurred with a group of testers who had three people playing. The moderator, along with the players, noticed that whoever played first was more than likely to win the game as they would be able to claim the most spots even if they lost a turn. Aside from this issue the testers were positively unanimous when asked if this version of the game was better than the previous version.

The feedback from the testers, along with observations of the moderator, and analysis of the post-play discussion made it apparent that the attempt at adding flexibility to the claiming of spots, along with reducing the size of the deck, had the expected outcome of improving gameplay and the enjoyment of players. The changes to the game rules and mechanics (trading cards, alternative means to win, etc.) also tested well. When asked what changes they would make to the game the testers asked to start with more than seven cards, strict enforcement of the time limit, giving everyone the same number of wilds and primes to start off with, and not playing the game with an odd number of players.

5 Playtesting Session Three

With the card deck finalized and the game rules set (see Fig. 10), the final area of focus in terms of the design of the game was on increasing the life or replayability of the game. This created a design problem, because using changes to the rules of the game and/or the mechanics would require additional playtesting. Seeing that the game rules and mechanics had been fully vetted, increasing the magnitude of the numbers on the board and the range of number on the board is a means of solving this design problem. It was hypothesized that increasing the number of squares on the game board, along with the range of numbers on the board would impact gameplay in several ways:

1. Increase the time needed to complete a round
2. Result in more passing or trading of cards
3. Increase the need for players to develop strategies for winning
4. Introduce the problem size effect (the larger the number the more time will be required for players to factor mentally).

Several game boards of varying size ($4 \times 4$, $5 \times 5$, & $6 \times 6$), created by randomly choosing from any number from four to one hundred, served to test the effect differing the board size and maximum number had on players perception of difficulty. The numbers one, two, and three did not appear on any of the game boards. Claiming spots for these number would be too difficult using three cards and based on the distribution of cards in the deck.
NYINGI IN A NUTSHELL
Players choose a board from the board pile based on difficulty. Each player is dealt 7 cards with the remaining ones placed face down to form a draw deck. The player to the left of the dealer goes first, with the winner of each round getting to start first after the first round.

In order for one to claim a spot/number on the game board, one must put down three cards that when multiplied together result in that number. For example, if a player wants to claim a spot numbered 36 they can put down a 4 card, a 1 card, and a 9 card (4 × 1 × 9 = 36). Once all other players have confirmed that the player has made a correct play, they can put their game piece on the board. Once a player has played three cards, they pick up three cards from the top of the draw deck and put the three cards they played at the bottom of the draw pile.

The only time a player can play just one card is when they have a prime card and use that prime card to claim prime number on the board. Prime cards can also be combined with two other cards to claim a spot. For example if a player wants to claim a spot numbered 84 they could play a 2 card, a 6 card, and a prime card. Before claiming the spot, the players must announce what prime number the prime card represents, in this case a 7. If the player incorrectly states a prime number, they lose their turn, must pick back up their cards, and must pick a card from the draw deck.

Wild cards are similar to prime cards in that they can be combined with two other cards, with the only difference being the wild card can represent any number. For example if the player wants to claim a spot numbered 100 they can put down a 10 card, a 2 card, and wild card. As with the prime card the player must announce what number the wild card represents before claiming the spot. If they are incorrect they must pick up their cards, pick a card from the deck and lose their turn.

If at any moment a player doesn't have a play, they have one of two options:

1. Pick a card from the top of the draw deck and lose their turn.
2. Trade up to three cards from their hand, with three cards from the top of the draw deck, and lose their turn.

If a player is taking too long to play, then anyone can call a time challenge. The player whose turn it is now has 20 seconds to play or lose their turn.

CHOOSING A DEALER
Each player picks a card. The player who picks the highest number deals. If you picked a "word" card, too bad, they don't count. Player to the left of the dealer starts play.

In addition to investigating how best to vary the difficulty of the game to increase replayability, this session sought to find out if players felt they were learning anything, and if so, what they felt they learned. The design team determined that this version of the game was robust enough in terms of playability to begin exploring what specifically Nyingi was teaching players and what players felt they learned as a result of playing Nyingi. As the model depicted in Fig. 4 illustrates, it is best to separate these two concerns (playability and learning), with the initial focus on playability. This makes it more likely to have a game that is engaging and educationally sound. As in previous playtesting sessions the game design team developed questions as a framework for the moderator to guide the playtesting session and to assist in the collection of observational data. These questions were:
1. What effect does increasing the size of the game board and the maximum number on the game board have on players’ perception of the game’s difficulty?
2. Do testers feel they learned anything through gameplay? If so, what?

5.1 Methods

5.1.1 Participants

As in the previous two sessions, the same twelve testers participated, as their familiarity with each of the previous versions of Nyingi is best suited for informing the third iteration of the game’s design.

5.1.2 Procedure and Data Sources

The moderator administered the same procedures and data sources from the first two sessions. The only change that took place was the moderator providing the testers with several game boards in order to ensure all players would interact with boards of varying size and magnitude of maximum number.

5.1.3 Results and Discussion

During the session, the moderator observed several comments by players that the larger boards with larger maximum numbers were more challenging. When asked about this after the session, testers actually registered preference for the larger boards. While this was surprising, it could also be a result of this being the third time this group of testers had played the game. The moderator also observed that playing a round of Nyingi with larger boards took longer to complete when compared to previous sessions, as anticipated. Testers liked the variety in game boards, and pointed out that having different game boards would help people learn the game and then be able to play more challenging rounds later.

A common theme derived from the comments made by the testers during the semi-structured focus group after the session, centered on the game changing how they thought about multiplication. Testers commented on thinking about multiplication as more than remembering fact pairs and of now having a better understanding of “breaking numbers down.” This speaks to the decomposition and prime factorization skills needed in order to be successful in the game.

An additionally theme gleaned from this session was the testers’ mentions of not really understanding prime numbers until playing the game. Some testers expressed initially thinking of prime numbers as odd numbers but then finding that to be a poor tool for determining whether a number was prime or not. Testers also mentioned finding it difficult to identify whether or not a number was prime, as the numbers on the board got larger. When the moderator brought up composite numbers, none of the testers indicated familiarity with the term, but they understood the relation of composite numbers to prime numbers once explained by the moderator. When asked how they approached determining if a number was prime or composite, testers shared a variety of rudimentary divisibility rules, such as determining if the number was even or odd and, if it was odd, seeing what numbers “went into the number” besides two.

Another interesting finding was a discussion led out by a few testers on saving one cards as a strategy. Several players mentioned understanding early on that one cards provided
them flexibility in claiming spots because those cards allowed them to focus on finding two cards whose product was the target spot instead of three. The moderator shared with the testers that this gameplay strategy was in fact an application of the identity property of multiplication. The testers who mentioned using this strategy were unaware of this multiplicative property.

Overall unanimously agreed that Nyingi helped them learn something new about multiplication and think about the operation as more than memorization of fact pairs.

6 Quasi-Experimental Study of Nyingi’s Learning Effectiveness

A quasi-experimental study followed the third playtesting session to investigate the effectiveness of Nyingi as a learning tool.

6.1 Methods

6.1.1 Participants and Design

The study had 17 participants enrolled in fifth grade at a school located in the Southeast United States. These participants were not enrolled in the same school as the playtesting group, so they had no prior experience with playing Nyingi. As this was a pilot study, it employed a quasi-experimental, one-group pretest–posttest design with no control condition (Shadish et al. 2002). Collection of posttest measures took place immediately after gameplay in order to control for the effect maturation may have on internal validity when using this quasi-experimental approach.

6.1.2 Procedures

Prior to gameplay, participants were given five numbers (24, 26, 36, 60, and 63) and directed to write as many combinations of three numbers whose product resulted in the given number. They had 2 min per number to complete this task. After completion of this task, the rules of the game were explained and the participants placed into groups of four to play, with one group having five players. Each group received game boards of various size and difficulty, game cards, player-specific colored claim pieces, and then instructed to play as many rounds as possible within an hour. The moderator guided the participants through two rounds of gameplay and then allowed them to play on their own. The moderator only provided assistance when questions arose concerning game mechanics and rules, and did not interject to ask questions as in the first three sessions. At the conclusion of 1 h, the moderator re-administered the tasks given at the beginning of the session. Finally, the moderator led out in a videotaped semi-structured focus group session in which the participants shared their thoughts about the game.

6.1.3 Data Sources

The following data was collected from participants prior to and after gameplay:

1. Total number of correct solutions
2. Total number of solutions using multiplicative identity property
3. Total number of unique solutions
Unique solutions were those that used different combinations of numbers. In other words, \(9 \times 1 \times 4\) and \(1 \times 4 \times 9\) would count as two correct solutions for 36, but would only count as one unique solution.

The following questions/prompts were drafted prior to the study to help the moderator guide the conversation during the semi-structured focus group:

- What were your general impressions of the game?
- Share with me something you liked about the game.
- Share with me something you did not like about the game.
- What were the most challenging aspects of the game?
- If you could change and/or add anything to the game, what would that be?
- Do you feel you learned anything from the game? If so, what?

### 6.1.4 Results and Discussion

Administering several paired sample \(t\) tests helped to evaluate mean differences between total number of correct solutions, total number of solutions using the multiplicative identity property, and the total number of unique solutions taken prior to and after gameplay. The results indicated that the means reported on the post gameplay measures were significantly greater than the means reported on the pre gameplay measures in regards to total number of correct solutions, \((M = 27.8, SD = 16.6), t(17) = 3.59, p < .01\), and the total number of solutions using the identity property \((M = 26.8, SD = 15.9), t(17) = 3.48, p < .01\). The standard effect size index, \(d\), was .87 for the total number of correct solutions and solutions using the identity property, as shown in Table 1. The 95% confidence for the mean difference between the pretest and posttest scores on total solutions and total solutions using the identity property were between 2.91–11.32 and 2.6–10.9 respectively (Fig. 11).

When asked to share general impressions of the game, participants responded that Nyingi was a great and fun way to learn their multiplication facts, prime numbers, factors, and multiplication in general. One tester shared this thought about the game: “what I think about the game is that the game helps you learn more while you’re having fun at the same time”. Another stated that the game could be motivating: “for those who don’t want to learn math this is going to be a fun way to learn their multiplication facts, factoring and prime numbers”. Finally, a tester commented on competition as an aspect of the game that was beneficial: “I like the game because it kinda makes you want to compete with the other people that are playing and you want to block them so they can’t win”.

### Table 1 Descriptive statistics and \(t\) test results for Nyingi pre/post measures

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Pretest</th>
<th>Posttest</th>
<th>(n)</th>
<th>95% CI for mean difference</th>
<th>(r)</th>
<th>(t)</th>
<th>(df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solutions</td>
<td>(M = 20.7)</td>
<td>(M = 27.8)</td>
<td>17</td>
<td>2.91, 11.32</td>
<td>.87*</td>
<td>3.59*</td>
<td>16</td>
</tr>
<tr>
<td>(SD = 15.0)</td>
<td>(SD = 16.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solutions w/identity</td>
<td>(M = 20.0)</td>
<td>(M = 26.8)</td>
<td>17</td>
<td>2.6, 10.9</td>
<td>.87*</td>
<td>3.48*</td>
<td>16</td>
</tr>
<tr>
<td>(SD = 14.9)</td>
<td>(SD = 15.9)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unique solutions</td>
<td>(M = 9.06)</td>
<td>(M = 10.5)</td>
<td>17</td>
<td>−3.03, .205</td>
<td>.67*</td>
<td>1.85</td>
<td>16</td>
</tr>
<tr>
<td>(SD = 3.49)</td>
<td>(SD = 4.13)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* \(p < .01\)
When asked if there was anything about the game they did not like, the discussion centered on the main game mechanic of using the product of three cards to claim a spot. As one tester said “the hard part was that you could only use three numbers”. One tester suggested allowing them to use more than three cards. This led to a disagreement on whether this rule change would help to improve the game. Those who advocated the use of more than three cards claimed that it would make the gameplay smoother and reduce the number of passes in the game. The counter argument was that increasing the number of cards to more than three would make the game too easy.

When asked about the most challenging aspects of the game, testers commented on the difficulty in determining game strategy, being limited to three cards, giving up a turn when they didn’t have a play, and identifying prime numbers. Some of the comments related to the challenging aspects of the game were:

- “What was challenging about the game was you had to block somebody. You had to find numbers in your hand to make that happen but it was hard if you didn’t have those numbers.”
- “What was really challenging was where you are ready to place cards down to claim a spot and somebody ahead of you claims that spot, you had to think of another number to claim or you had to draw cards and I don’t like drawing cards.”
- “I think what was challenging about the game was that you had to draw and you had to know what prime numbers are.”
- “I think it was challenging because like usually we just do 1 × 7 instead of 1 × 7 × 5.”

Finally, when asked what they would change about the game, the discussion returned to the topic of increasing the number of cards one could play during their turn. One tester who advocated keeping the three-card limit the same made the following suggestion: “Like, you could add two numbers and put the plus sign wherever you want.” When asked if they were suggesting the inclusion of other operations besides multiplication in the process of claiming a number, all testers expressed enthusiasm for this approach and several provided examples of how this would work.
6.2 Future Directions for Nyingi

The design team will continue refining Nyingi based on the feedback and results of three playtesting sessions and a quasi-experimental study. Nyingi 2.0 will be a digital version and tested within several classrooms in order to determine the effectiveness of the game as a tool in the instruction of multiplicative properties, strategies, and concepts. It is easy to imagine the game serving as an instructional tool for more than just factorization. This game could possibly teach and/or assess a variety of important concepts, such as:

- Associative property
- Decomposition
- Prime and composite numbers
- Prime factorization
- Greatest common factor
- Least common multiple
- Parenthesis
- Distributive property
- Divisibility rules

Mastery of these concepts should occur between grades four through six. The next phase of this project will focus on these grades by development curricular materials to go along with the game.

7 Conclusion

The purpose of this study was to explore how to improve an educational game by focusing on playtesting and iterative refinement. Based on the results of the playtesting sessions it is evident this model shows promise. Achieving a balance between attention, arousal, affect, and intrinsic integration was demonstrated with the development of Nyingi. Most importantly the quasi-experimental study found on average, participants showed significant gains in their ability to factor whole numbers along with support for the engagement and motivational aspects of the game.

The gold standard for all educational game designers is to “make a great game that engages players and provides educational impact” (Fay 2014, p. 252). The iterative design and development model used in the creation of Nyingi provides a direct path to accomplishing this by focusing on playtesting prior to focusing on learning. The time spent in playtesting Nyingi was invaluable as it served as a low-cost method of verifying the proper application of intrinsic integration and iterative refinement as a guiding game design principle. Most importantly, this process helps verify if the game is enjoyable, replayable, and most importantly, if learning takes place as a result of gameplay. Finally this work provides game designers with several best practices that should be integrated into their praxis:

1. Achieving intrinsic integration is paramount during the concept phase.
2. Playtest early in the game development process and playtest often.
3. Playtest with the target population.
4. Create a playtesting environment conducive to gathering useful feedback.
5. Ensure learning derives directly from gameplay and is impactful.
Hopefully this work will encourage educational game designers to spend time in low-cost, paper-based playtesting prior to creating a digital version of a game in order to maximize the return on investment. This allows for the simultaneous confirmation of whether a game is good and if it can truly be considered a learning game.

References

Improving Learning and Engagement within Digital Games for Learning Through Intrinsic Integration and Play Testing

Objective

Designing and developing games for learning is a difficult endeavor. Educational game designers are tasked with not just making an engaging and motivating game, but ensuring that learning takes place as a result of gameplay. Educational researchers have sought to define design principles in order to lessen the difficulty involved with game design (Nelson et al, 2005; Barab, 2007; Squire & Klopfer, 2007). In spite of these efforts, there is still a paucity of empirical research in support of significant direct learning gains resulting from time spent in a game environment (Honey & Hilton, 2011; Li & Tsai, 2013). The purpose of this study was to investigate the effectiveness of a design and develop approach centered on play testing in order to ensure the proper intrinsic integration of multiplication properties, concepts, and strategies within the game’s mechanics. It was hypothesized that this design strategy would result in the creation a truly engaging educational game.

Theoretical framework

There is a rising interest in the instrumentation of games for educational purposes. Researchers, theorists, and practitioners are interested in the use of games for learning for a variety of reasons, most of which are related to the inherent characteristics of games. Games are goal-oriented, along with being engaging and motivating. Games provide continuous feedback on performance, require participants to think critically, allow participants control over the environment, and are excellent at creating endogenous value (Wong, 1996; Gee, 2004; Prensky, 2005; Shaffer 2006; Tobias & Fletcher, 2011). These characteristics are representative characteristics of an ideal learning environment. It is therefore easy to see the interest in the use
Those involved in the design and development of games will readily agree with the statement that all games aren’t good games (Gee, 2005; Van Eck, 2006). Many times attempts at creating digital games for learning many times results in failure or inconclusive findings. There are two factors contributing to this. Firstly educators directly involved in the creation of games for learning are not skilled game designers. The games they create are pedagogically sound educational technology, but lack the elements needed to make the game engaging and motivating (Van Eck, 2006). What good is a game if no one wants to play it? Secondly, experienced game designers are capable of creating rich, immersive game environments, which encourage hours of game play, but are unaware of learning theory and pedagogy, and therefore unable to develop games that assist players in achieving instructional objectives and/or producing learning gains as a direct result of game play (Van Eck, 2006).

In order to address issues related to the creation of good games for learning, a variety of design strategies have been investigated. Of these game design strategies, intrinsic integration has shown exceptional promise. Intrinsic integration, which is an extension of Malone & Lepper’s theory of endogenous games, adds the additional focus on flow, core mechanics, and representations (Habgood, Ainsworth, & Benford, 2005). Habgood et al., contend that in order to achieve the gold standard of engagement and learning within an educational game, careful attention must be placed on creating a feeling of flow, or “total concentration, distorted sense of time, and extension of self, which are feelings that can be identified by anyone completely engaged on a task” (Habgood, Ainsworth, & Benford, 2005, p. 492). Core game mechanics are the “mechanisms through which players make meaningful choices and arrive at a meaningful play experience” (Salen & Zimmerman, 2004, p. 317). Careful attention to the core game
mechanics help to achieve flow by supporting continued player interaction with learning objectives, presenting challenging tasks, providing learner control, and fostering cooperation and competition (Habgood, Ainsworth, & Benford, 2005). The final design focus within intrinsic integration looks at the representations used in the game. Research has found that within GBL environments, the more representative the structures and interactions within the game are with the instructional objectives, the more beneficial they are for learning (Reiber, 1996; Papert & Talcott, 1997; Miller, Lehman, & Koedinger, 1999; Ainsworth & Loizou, 2003, & Martin & Schwartz, 2005).

Habgood conducted several empirical investigations in an attempt to determine the effectiveness of applying intrinsic integration strategies to the design and development of GBL environments. Habgood (2011) developed Zombie Division, a game created to teach whole number division, and conducted an investigation in which three versions of the game were tested for player enjoyment and ability to support learning. In an empirical study, Habgood found those who played the intrinsic integration version of Zombie Division significantly outperformed all other conditions on measures of learning and engagement. Additionally those who played the intrinsically designed version of the game maintained their significant learning gains on a delayed posttest. These findings have been supported by Author (2013), who reported on the design and development of a game designed to teach multiplicative properties and support automaticity of multiplication facts. Those who played the intrinsically designed version of the game had significantly higher learning gains than those who did not and were on average significantly more likely to want to continue playing their version of the game when compared to those in the other conditions.

While intrinsic integration shows promise, more work needs to be done. This study seeks
to contribute to the work being done on intrinsic GBL design and development by concentrating on play testing prior to a full-scale empirical study. Iterative refinement of a game prototype may help to achieve the gold standard of high levels of engagement, motivation, and learning within GBL environments. Unfortunately this is an activity that is rarely reported on within GBL literature. This manuscript reports on a play testing session, whose intent was to speak to the refinement of *Nyingi*, a game designed and developed to teach multiplicative factorization.

*Nyingi*, is a board game that is a combination of Bingo and Uno. The goal of the game is to win either by claiming the most spots on the game board, or by claiming a diagonal, horizontal, or vertical row of numbered spots on the board. In order for one to claim a spot/number on the game board, one must put down three cards that when multiplied together result in that number. For example, if a player wants to claim a spot numbered 28 they can put down a 2 card, a 2 card, and a 7 card (2 x 2 x 7 = 28). There are 54 cards in the deck numbered 1-10, along with wild and prime cards. Wild cards can be used to represent any number, and prime cards can be either used to claim a prime numbered spot or used as a prime number in a grouping of three. In both cases the player must state aloud what that number is.

![Figure 1. Sample Nyingi Game Board](image)
Version 1.0 of Nyingi, consists of a variety of game boards of varying size (3 x 3, 4 x 4, 5 x 5, and 6 x 6) and difficulty. Increasing the size of the game boards, the number of numbers with prime factors on the board, and numbers on the board themselves were the factors used to determine the difficulty of the game board.

**Methods**

A study was conducted to explore the effectiveness of Nyingi in terms of supporting learning and engagement. The study had 17 participants enrolled in fifth grade in a school located in the Southeast United States. This study employed a quasi-experimental design with no control condition. Prior to gameplay participants were given five numbers (24, 26, 36, 60, and 63) and asked to write as many combinations of three numbers whose product resulted in the given number. They were given two minutes per number to complete this task. After completion of this task the rules of the game were explained and the participants were divided into groups of four to play (one group had 5 players). They were provided with game boards of various size and difficulty, game cards, player specific colored claim pieces, and then asked to play as many rounds as possible within an hour. At the conclusion of the hour the participants were re-administered the task given at the beginning of the session. Finally a videotaped focus group session was conducted in which the participants were asked to share their thoughts about the game.

**Data Sources**

The tasks participants completed prior to and after gameplay allowed for the following data to be collected:

1. Total number of correct solutions,
2. Total number of solutions using multiplicative identity property
3. Total number of unique solutions

Unique solutions were those that used different combination of numbers. In other words, $9 \times 1 \times 4$ and $1 \times 4 \times 9$ would count as two correct solutions for 36, but would only count as one unique solution.

Results

Several paired sample $t$ tests were conducted to evaluate mean differences between total number of correct solutions, total number of solutions using the multiplicative identity property, and the total number of unique solutions taken prior to and after gameplay. The results indicated the means reported on the post gameplay measures were significantly greater than the means reported on the pre gameplay measures in regards to total number of correct solutions, and the total number of solutions using the identity property.

Table 1

Descriptive Statistics and $t$-test Results for Nyingi Pre/Post Measures

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Pretest M</th>
<th>Pretest SD</th>
<th>Posttest M</th>
<th>Posttest SD</th>
<th>n</th>
<th>Mean Difference</th>
<th>r</th>
<th>t</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Solutions</td>
<td>20.7</td>
<td>15.0</td>
<td>27.8</td>
<td>16.6</td>
<td>17</td>
<td>-11.3, -2.91</td>
<td>.87*</td>
<td>-3.59*</td>
<td>16</td>
</tr>
<tr>
<td>Solutions w/Identity</td>
<td>20.0</td>
<td>14.9</td>
<td>26.8</td>
<td>15.9</td>
<td>17</td>
<td>-10.9, 2.67</td>
<td>.87*</td>
<td>-3.48*</td>
<td>16</td>
</tr>
<tr>
<td>Unique Solutions</td>
<td>9.06</td>
<td>3.49</td>
<td>10.5</td>
<td>4.13</td>
<td>17</td>
<td>-3.03, .205</td>
<td>.67*</td>
<td>-1.85</td>
<td>16</td>
</tr>
</tbody>
</table>

* $p < .01$.

In regards to the focus group, when asked to share general impressions of the game, participants responded that *Nyingi* was a great and fun way to learn their multiplication facts, prime numbers, factors, and multiplication in general. One respondent also mentioned it helped them think about multiplication in a different way, and another enjoyed the competition the game fostered. When asked about the most challenging aspects of the game, participants mentioned determining game strategy, being limited to three cards, having to give up a turn when they didn’t have a play, and
identifying prime numbers. Finally some participants wanted to be able to use more cards, and most interestingly, there was overwhelming support to be able to use other operations within the game.

**Scientific and Scholarly Significance of the Study**

The purpose of this study was to explore how well a GBL environment intrinsically integrated factorization. Based on the results of the play testing session it is evident that *Nyeringi* shows promise in this regards. On average participants showed significant gains in their ability to factor whole numbers. Additionally there was overwhelming support for the engagement and motivational aspects of the game. Furthermore there is support for the game to be used as an instructional tool for more than just factorization. This game could possibly be used to teach decomposition, prime and composite numbers, least common multiples, greatest common factors, and the associative and distributive properties of multiplication. The time spent in play testing prior to making a digital version of *Nyeringi* was invaluable as it served as a low cost method of verifying the proper application of intrinsic integration GBL design principles, and verifying the game is enjoyable and learning takes place as a result of game play.

Hopefully this work will encourage GBL designers to spend time in low-cost, paper-based play testing prior to creating digital versions of games in order to maximize their return on investment, while simultaneously confirming whether they have a good learning game.

**Future Directions**

Based on the feedback and results of this study, *Nyeringi 2.0*, will be developed. *Nyeringi 2.0* will be a fully digital version of the game and will be tested within several classrooms in order to determine the effectiveness of the game as a tool in the instruction of multiplicative properties, strategies and concepts. Additional work will also be done on developing an algorithm to match
board difficulty to the level of the players and investigating the use of the game as a formative assessment.


HOW TO PLAY

AGES: 9 and over

PLAYERS: 2 to 4

OBJECT:
To be the first player to win by either claiming all the numbers on a diagonal, vertical, or horizontal line of numbers. You can also win by having the most numbers claimed on the board once all numbers/spots have been claimed. First person to win 7 rounds wins the game.

YOU SHOULD HAVE - Two decks, each containing 54 cards as follows:
8 1/Blue Cards
8 2/Green Cards
5 3/Red Cards
3 4/Yellow Cards
3 5/Orange Cards
3 6/Purple Cards
2 7/Pink Cards
2 8/Black Cards
2 9/Indigo Cards
2 10/Alabama Crimson Cards
8 Prime Cards
8 Wild Cards
10 Easy Game Boards
10 Intermediate Game Boards
10 Advanced Game Boards
1 Blank “Do-it-Yourself Board”
1 Dry Erase Marker
1 Mini Eraser
1 List of Random numbers
1 Minute sand timer
80 Player Chips
20 White
20 Blue
20 Red
20 Purple