# Are We Washing Poop?: Unintended Consequences in Educational Game Design

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**Abstract:** What game developers and researchers know about what makes games enjoyable for children does not always transfer well to educational contexts. This paper highlights potential pitfalls that may arise when creating a game that attempts to integrate learning and fun using a case study of *Down With Food*, a game that teaches upper elementary school students about the digestive system. We employed game mechanics and game design usability heuristics in our development of this iPad application. User testing revealed areas in which applying general game principles to an educational context created concerns, particularly with respect to the effects of schemas, visual misrepresentation, and usability issues. In detailing these unintended consequences, we hope to spur productive discussions about how to address the challenges of bridging the fields of game design and education.

## Introduction

*"To make this game 'scientifically accurate' we would be making kids watch blobs of food change in imperceptible ways for about 18 hours."* -Neil Young, game designer, *Down With Food*

Education and entertainment are typically ascribed the "oil and water" metaphor because they never quite seem to mix well, evidenced by mountains of neglected educational games that reek of fake fun (Bruckman, 1999). Children rarely reach for games that are too heavily saturated with "learning" concepts because they prefer their diversion time to be a break from the hours spent at school. Whether this is an issue of educational content that simply cannot be made fun with complete accuracy, as suggested in the quotation highlighted above from our game designer, or the ever-developing understanding of what it means to fuse learning and fun into one game, it is our goal to shed light upon strategies that game developers can use to leverage game mechanics in education. Deviating from traditional educational games that treat "fun" as separate and secondary to learning, our design decisions were largely geared toward leveraging the aspects of games that make them appealing and enjoyable, and integrating those aspects into the development of educational content. Through iterative user testing and applying findings from research in cognitive and educational psychology, we have gained insight into the nature of design challenges that occur when trying to truly fuse fun and learning into an educational game. After studying and implementing specific elements of game-based design, such as leveraging the affordances of the iPad and understanding the gaming experiences children have, we present a case study on the development of *Down with Food*, an educational mobile app created to teach children ages 7-12 about the human digestive system.

We created *Down With Food* to teach young children about the digestive system through a series of mini-games that are each based on attempts to apply popular game mechanics to an educational context. As a multidisciplinary team, we often encountered disputes among our educational researchers, designers, and programmers when trying to negotiate seemingly separate goals. Our conversations have been crucial to understanding the complexities involved in making an educational game.

The first consideration in negotiating a scientifically accurate depiction of biological processes and transforming it into a fun, playable game was our deliberate use of fantasy. While fantasy elements may detract from learning aspects if children are unable to differentiate biological processes from gameplay, creating a virtual reality is a key element to get learners immersed in game play. In *Making Learning Fun*, Malone and Lepper (1987) produced a taxonomy identifying four categories of individual motivation responsible for the positive effect created by computer games. Along with challenge, curiosity, and control, this taxonomy includes incorporating the element of fantasy (Malone & Lepper, 1987). To incorporate fantasy elements into *Down With Food*, we deliberately used "tower people" as enzyme launchers that players can drag and drop along the lining of the small intestine (see Figure 1). Allowing players to place multiple towers from which to release enzymes in the small intestine mini-game is not scientifically accurate because there is only one duct from which enzymes are released within the small intestine. Prioritizing gameplay was deemed more important in garnering players' interest. Additionally, knowing which elements of the game learners take with them needs to be explored further. Our team felt it was more important that players understand enzymes are needed to absorb nutrients than the fact that these enzymes are all released from

one duct at the beginning of the small intestine, instead of from many depicted by the “tower people”.

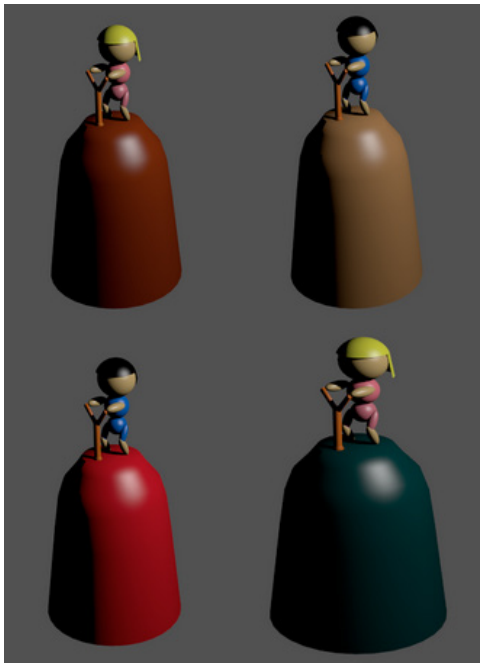

**Figure 1: The enzyme “tower people”.**

## *Down With Food*: How it’s played and what it teaches

To find a balance between education and entertainment, we looked at game design principles followed by popular games to determine which principles to consider when creating our own game. A game that implements intrinsic integration is one in which the designer integrates the subject matter with the game idea (Kafai, 1996). Because there is currently no definite method for evaluating the effectiveness of intrinsic integration in a game, we designed our game based on general usability principles proposed by Pinelle, Wong, and Stach (2008), who describe ten design heuristics after searching through online reviews for various video games. From these ten principles, we based most of our initial design on those that focus on game play mechanics, instead of those that focused on customization and artificial intelligence.

To study intrinsic integration and implement Pinelle et al.’s (2008) usability design heuristics, we used *Down With Food* to observe the effects of game design in user testing sessions. *Down With Food* contains a collection of mini-games that explore how the digestive system works by allowing players to follow the process from when the food enters the mouth until it is released from our bodies. Each mini-game focuses on a different organ involved in the digestive process. Our initial focus is on the small intestine mini-game, which imitates the design and gameplay of Tower defense games, a subgenre of real-time strategy games in which players typically place static units to defend against mobile enemy units attempting to traverse a game map. After considering several different genres of games, we decided to adopt the Tower defense paradigm because of its popularity, and the fact that its gameplay most closely matches the processes that occur in the small intestine. The interaction between the enzymes and the food passing through the small intestine is similar to that of towers and incoming waves of enemies in many traditional Tower defense games.

In the small intestine mini-game, players place enzyme towers that release enzymes (for fat, protein, lipids) that break down the food as it passes through the small intestine. Each food blob has to be in contact with certain types of enzymes to be broken down and have the nutrients contained within the food blob absorbed by the villi located throughout the small intestine. In addition to these gameplay mechanics, *Down With Food* provides persistent health and nutrient counts to show the player’s status throughout the game. The health count reflects how healthy the character is. If food is not completely broken down, then the character’s health decreases. The nutrient count keeps track of how many nutrients have been absorbed after breaking food down by applying enzymes to food blobs. Certain amounts of nutrients are needed to build certain enzyme towers. Through this game, our goal is to demonstrate the process of enzymes breaking down the food into nutrients, which are then absorbed by the villi.

## Application of Game Design Usability Heuristics

We based our mini game on four of the ten usability design principles described by Pinelle et al. (2008). The first principle we considered is providing "consistent responses to the user's actions" (Pinelle et al., 2008). Our design allows players to drag each tower and to place the tower only on the lining of the small intestine. The second principle we implemented involves "providing controls that are easy to manage and have an appropriate level of sensitivity and responsiveness", by having the towers light up when they are dragged to a place where they can be set (Pinelle et al., 2008). As soon as the tower the player's finger is dragging is directly on top of the lining, the towers can be placed there. The design is sensitive and makes sure that the towers are dragged and dropped exactly where the lining in the game is located. The third principle we use in our design is "providing users with information on game status" (Pinelle et al., 2008). We show nutrient and health status counts; the health status to display information to players about how healthy their character is throughout the game, and the nutrient count to display how many nutrients they have available to build additional enzyme towers. The last principle we considered and implemented in our mini-game is "providing instructions, training, and help" (Pinelle et al., 2008). Before players can play the mini-game, players are first shown instructions that describe which food blobs should be broken down by which enzyme towers, to ensure that players understand how the gameplay works. The other six principles described by Pinelle et al. involve heuristics for games that involve more plot-based gameplay, rather than for mini-games like ours. Hence, we did not take these principles into consideration while designing our game.

## Insights from user testing: Unintended consequences

During our user testing sessions, we had seven children, between the ages of 4 and 10, play our small intestine mini-game. During gameplay, we asked each child to describe his or her own thought process out loud. After they finished playing the small intestine mini-game, we asked the participants what they thought was happening in the game and whether they thought the game was fun.

## Schemas

Pre-existing knowledge and perceptions that players have about a game can affect how players learn to use the game and how players understand what is happening in the game. In our small intestine game, we wanted to show that the towers shoot enzymes at the food blobs to break them down and that nutrients get absorbed by the outer villi projections afterwards. Tower defense games typically ask players to strategically place towers to ward off oncoming enemies. In our game, players need to place towers along the small intestine and shoot enzymes at oncoming food. The oncoming "enemy" in our game is actually an "ally" for survival. To our surprise, many children were not able to grasp that concept. For instance, one child explained to us that "the towers are attacking the food because the food is something bad," a statement that would be completely in line with mechanism upon which most Tower defense games operate, but is clearly not true in the case of food breakdown within the small intestine. One possible explanation for this misconception is that the goal of most Tower defense games involves strategically placing towers in order to attack passing enemies and defeat them. Children who might have previously played Tower defense games, or are familiar with them, have developed a schema that Tower defense games involve attacking or killing waves of enemies, so when playing something new that mimics the design of such games, they associate the Tower defense game schema with the new game.

## Visual Misrepresentation

Graphical representations have nuanced ways of influencing children's' interpretation and understanding of educational content in games. For example, in *Down With Food*, when the towers hit the food blobs, the nutrients to be absorbed by the villi were represented as several glowing colored dots to demonstrate that they were broken down. As one child was playing, she noticed these dots (see Figure 2). When asked what she thought was happening, she stated that "[the enzymes] were washing the poop". When asked why she believed that, she commented that the green dots looked like soap suds, which we did not intend. What we designed to help players understand that the nutrients are broken down in the small intestine was instead perceived as washing. As previously discussed, many children described the scene as the towers attacking or killing the passing food blobs. One child even described it as "the towers eating the food blobs." Along with the schema most players have of Tower defense games, the graphics in our mini-game show the enzymes as bullet-like projectiles being shot from the enzyme towers. The food blobs are seen as enemies destroyed by bullets from the towers, with the towers as the "good guys" and the food as the "bad guys". These examples demonstrate how visual misrepresentations, combined with schema effects, can cause unintended misconceptions when trying to integrate learning and fun.


**Figure 2: Visual effect produced when enzymes hit food blobs, breaking the food down into nutrients.**

## Usability Issues

During our user testing sessions, we discovered that, even as we based our game on Pinelle et al.'s (2008) usability heuristics mentioned above, we still encountered some usability problems. We found that during the testing sessions, in many cases the game did not give enough allowance for children to place the towers. Often, the children would drag a tower to a position just a short distance from the lining of the small intestine, and would release the tower, thinking that the tower could be successfully placed. However, because the tower had been placed in a position slightly off the intestinal lining, the tower would fail to be placed, and the player would be forced to try again. This corresponds with Pinelle et al.'s (2008) principle of the sensitivity of game controls, as well as the principle involving consistent responses from the player's actions. Because children are still developing their motor control and hand-eye coordination, they are unable to keep their finger on the same spot for an extended amount of time. As such, considerations that include understanding child development need to be incorporated into design. Also, our controls were too responsive and the allowances for not placing the towers directly on top of the lining affected gameplay by forcing the player to sometimes try placing towers more than once. Furthermore, the point system that relays nutrient and health counts went unnoticed by the players, who didn't understand why they occasionally could not build new towers. While we did follow the usability principles proposed by Pinelle et al. (2008), we learned that game design for a younger audience should allow for more room for error. This demonstrates that considering child development is very important in game development and that the age of the player can result in different responses to different designs. As such, appropriate scaffolds must be integrated into the game.

## Future Design and Directions

How can we change the Tower defense schema to reflect that enzymes are breaking down the food and allowing the body to absorb nutrients, rather than allowing the misconception of towers shooting the food to continue? First, we can provide more visual support to lead learners into understanding the intention of our graphics. Designing graphics to more accurately portray what is happening in the small intestine, such as modifying the visual effects produced when the enzymes start breaking down the food can help. Instead of understanding our towers as warding off an enemy, they should come to understand our towers as aiding in the digestion of food. Furthermore, sounds with a more

fantastical element can be used to portray the beneficial process of breaking down the food in the small intestine, further reinforcing the benefit of absorbing nutrients.

More sophisticated methods of evaluating games based on intrinsic integration are necessary to progress in the genre of fun educational games. While intrinsic integration is a theoretically grounded solution to the problem of fusing learning and education, it is difficult to evaluate because best practices around its implementation have not yet been established. In order to create a dialogue around the validity and plausibility of implementing

intrinsic integration in games, we will present findings from further user testing sessions as a starting point for the larger conversation.

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