# Negotiating representations of scientific phenomena during the development of games for learning


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**Negotiating representations of scientific phenomena during the development of games for learning**

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Prototype software development began in early March 2009. The team holds weekly teleconferences to enable the instructional designer, the production manager, the game designers, and the science content experts to review each new iteration of the prototype and discuss science, instructional design, game play, and visual design as a group. These calls are followed by reviews by individuals and small groups within the EDC/CCT team with the resulting comments, questions, and concerns collected by the production manager and forwarded on to the game designers.

The first round of prototyping began with puzzle-like mini-games that attempted to provide a playful experience of interacting with the transformation of energy during photosynthesis and respiration. The main learning goal of the module is to dispel common, identified misconceptions about the nature of photosynthesis—such as the notion that soil contributes mass to a plant—by having students engage with mechanics, game play, and representations that help them enact the process of using energy to transform gas into a solid. Users can then apply what they have experienced to challenges in other mini-games.

1st Playable Productions uses the PC-based game authoring tool Game Maker (see Figure 1), that allows for visual emulation of the Nintendo DS and the interactions and mechanics of the Nintendo DS on the screen of a PC. Button functionality can be mocked-up and players use a mouse instead of a stylus on the bottom touch screen. This rapid prototyping environment makes it easy to iterate mechanics and artwork for evaluation by the designers, and play testing before coding begins on the proprietary and less flexible Nintendo development environment.

**Figure 1** Game Maker DS Emulator shown on PC screen.

The initial production schedule called for an approximately six month development period for Module 1, with two iterations in the Game Maker environment and one iteration for Nintendo DS development for each mini-game.

The first prototype attempted was the “cell puzzle,” in which a player manipulates the process of photosynthesis on the cellular level on the touch screen and sees the effects of that manipulation on the plant in the status screen.

In the game, students direct the sun’s energy into a plant leaf. By blasting the sunlight toward molecules of carbon dioxide (a gas) and water (a liquid), they initiate the break down of these materials and the subsequent reassembly of atoms into sugar, or glucose, molecules (a solid). Later in the game, they can explore the process of respiration. By blasting oxygen molecules toward the glucose, students witness the breakdown of glucose and the consequent release of stored energy. When energy is released, students are able to see the impact on the overall health and size of the plant represented on the upper Nintendo DS screen. Through repeated manipulation of the photosynthesis process, we believe students will deepen their understanding of chemical change. They will also begin to internalize the understanding that there is no “eating” involved a plants’ production of food, and that soil has no role in photosynthesis.

1$^{st}$ Playable’s initial approach was to create a game challenge on the touch screen that was at the molecular level, where users would have to break apart $CO_2$ and $H_20$ and then re-assemble the resulting particles into glucose. Players could see feedback in the form of animations of plant health and growth on the top screen. The particles had a lively bouncing action and the challenge entailed organizing, grouping and circling needed particles with a lasso-like use of the stylus/mouse. (Figure 2)


**Figure 2** First Game Maker Iteration of Cell Puzzle.

It was during the review of this first iteration that the team began to delve deeply into one of the central challenges of creating games for science education: what tradeoffs must be made in natural verisimilitude in order to create compelling game play? Careful review of science content is needed to preclude the establishment of new misconceptions, but artistic license must be allowed to simplify and amplify mechanics that can sustain player interest.

Rather than two iterations of the first mini-game, the production team went through four versions. The team encountered challenges pertaining to scientific accuracy and appropriate visual representation in the early prototypes. Creating thinking games that address concepts rather than delivery of content information on a game platform raised several key design questions that are discussed below.

*Question 1: Are the game mechanics relevant to the content and the learning? E.g. does the player manually and conceptually enact a process that reinforces the phenomena being represented?*

In Figure 3, an early prototype shows one carbon and two oxygen particles being circled by the stylus to combine to make $C0_2$.

**Figure 3** Early iteration showing **a** circling mechanic to combine particles.

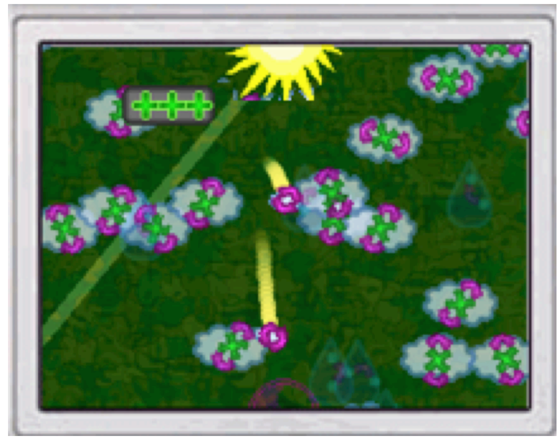

**Figure 4** Later iteration showing a shooting mechanic that directs energy towards particles.

After review, the team determined that the circling mechanic had no metaphorical connection to the energy transformation and did not really promote thinking about energy's role in photosynthesis. Figure 4 shows a later iteration of the game where a "shooting" mechanic was introduced to give the feeling to the player that they were enacting energy being directed at the particles in order to break them apart.

*Question 2: Are particles represented in a meaningful way that helps students understand the forms of matter involved in photosynthesis? E.g. Gases being transformed into solids.*

**Figure 5** Early iteration showing oxygen molecules as balls and glucose represented as a sugar cube.

**Figure 6** Later iteration showing glucose in a schematic form representing how the component particles bond to form a molecule.

After review of the early prototype (Figure 5) by the science team, we decided that students would be better served by the particles being illustrated in a way that conveyed the form of matter they represented. For instance, carbon dioxide would be shown as a cloud shape, water a droplet, and carbon as four-sided polygon shape, to represent a solid. Glucose would be shown as a collection of particles (Figure 6).

*Question 3: Is the scale of the illustrations appropriate? Will conflicting representations of size create or reinforce misconceptions (e.g. depicting molecules visibly floating around in a cell organelle)? Does relative scale need to be consistent or realistic?*


**Figure 7** A later prototype showing on the top screen carbon dioxide, oxygen, and water represented as visible particles in the atmosphere in order to reinforce the main components of photosynthesis.

After review of early iterations, the science team decided that invisible particles could be shown as visible to reinforce the main components of photosynthesis. To a certain extent all depictions of atomic particles are conceptual and our theory is that students will be able to understand that these illustrations are not to scale. These representations will be tested with teachers and students before final Nintendo DS programming begins.