Build-a-Tree: Parent-Child Gaming to Learn About Evolution in Museum Settings

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Introduction

We present Build-a-Tree (BAT), an evolution puzzle game for natural history museums. BAT asks players to construct phylogenetic trees (also known as cladograms) using tokens depicting species and traits. We seek to understand how visitors learn about evolution through interactions with each other and with our game. We provide an overview and rationale for our game design and share preliminary findings from a study of parent-child dyads playing BAT in a natural history museum.

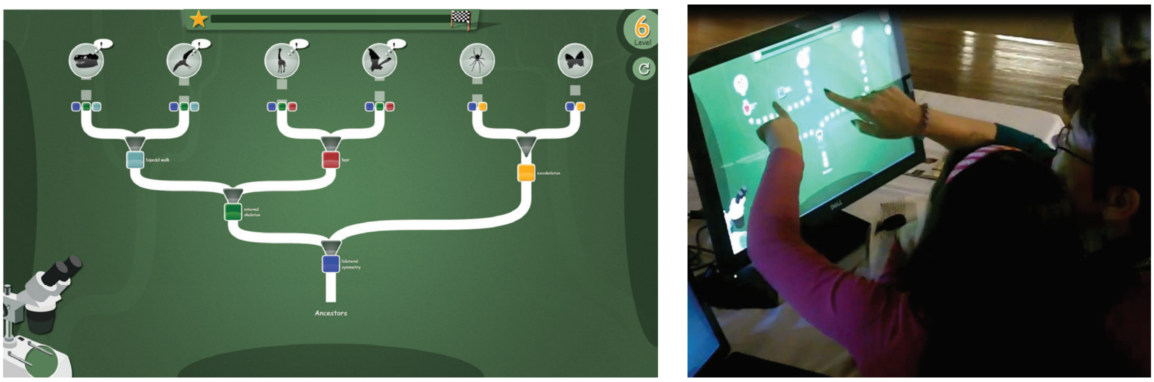

Figure 1: *Build-a-Tree* is an interactive, game-based tabletop exhibit designed to facilitate learning about evolution in natural history museums.

Evolution as a Critical Public Issue

Evolution is the central organizing theory that explains the diversity of life and explains similarities and differences among species (National Academy of Sciences, 1998). Given its importance, findings about the general public's awareness and understanding of evolution are both informative and worrying. Over the past two decades, the percentage of American adults who accept evolution has decreased from 45% to 40%; perhaps more alarming is the change in the percentage of adults who have become unsure about evolution—this has risen from 7% to 35% (Miller, Scott, & Okamoto, 2006). Additionally, surveys have shown that large segments of people, including museum visitors, have little to no understanding of evolution (Smith, 2010; Evans, 2006).

The Role of Museums

Natural history museums are uniquely positioned to help the general public learn about evolution (Diamond & Scotchmoor, 2006). These museums typically feature "life over time" exhibitions, in which visitors can view dioramas that recreate communities with paleontological specimens to reflect particular points in Earth's history (Tubutis, 2005). These exhibitions, which often feature towering reconstructions of dinosaurs and early humans, attract significant visitor attention and museums have tended to devote the greatest amount of floor space to these attractions (Tubutis, 2005). In addition to their content and collections, museums also command consistent and extraordinary trust from the general public (Semmel and Bittner, 2009). In a survey conducted by the Institute of Museums and Library Services, 77% of the 1700 adults surveyed rated museums as higher in trustworthiness than all other sources of information, including the government or commercial and private websites (Semmel and Bittner, 2009; Griffiths, King, and Pomerantz, 2008). This trust is critical when we consider the increasing lack of acceptance of evolution and recent calls to incorporate intelligent design and creationism into classrooms (Berkman and Plutzer, 2011; Beckwith, 2003). Museums can use their role as trusted sources to tackle issues of inaccuracy by fostering "a climate of healthy skepticism, in which all truth claims are weighed carefully [and] ethical commitments [are made] to identifying and reporting the truth" (Jenkins, 2006).

Interactive Surfaces

Large interactive surfaces have gained increased attention in recent years and researchers and educators alike are interested in their use for science learning. Because these devices allow multiple users to interact concurrently, they have a unique potential to support collaborative learning through engagement with digital content. Their ability to “support awareness of other’s actions and [their] ability to support concurrent input” gives agency to every engaged learner while providing incentive for individuals to interact with each other (Rick, Marshall, and Yuill, 2011). Learners around a shared display typically negotiate their actions not only to avoid interfering with each other’s intentions but also to coordinate their efforts so that they may successfully and efficiently complete tasks (Rick, Marshall, and Yuill, 2011; Dillenbourg and Evans, 2011). Others have pointed out the potential of interactive surfaces to allow learners to directly interact with representations of natural phenomenon (National Research Council, 2011) and to manipulate both virtual and physical objects (depending on the design) to solve problems (Antle, Bevans, Tanenbaum, Seaborn, and Wang, 2011).

Games for Learning

Games have, under controlled circumstances, proven to be effective instructional tools that can have a positive impact on science knowledge and attitudes (Honey and Hilton, 2010). Three key aspects of video games that make them attractive to both researchers and science educators are 1) their built-in scaffolds through their leveling-up structure, 2) their risk-free character, and 3) their encouragement of social interaction, which often leads to collaborative problem-solving (Gee, 2005). Games involving a well-designed progression of levels allow players to learn new information at each level which keeps them engaged as new tasks are added (Weppel, Bishop, and Munoz-Avila, 2012; Melero, Hernandez-Leo, Blat, 2011; Gee, 2005). By unveiling new information and tasks at each level, players feel compelled to advance through the game in order to learn more and hone their increasing expertise. Games can also encourage experimentation and productive failure without risk by promoting play (Salen and Zimmerman, 2004), making them an ideal instructional tool for science (National Research Council, 2011). The combination of experimentation and a risk-free setting allows players to learn and practice behaviors and thought processes while remaining highly engaged (Salen and Zimmerman, 2004). Lastly, games can lead to problem-solving that is collaborative in nature (Stevens, Satwicz, & McCarthy, 2007). Gaming is play across social spaces and networks, which means it includes engagement with parents, siblings, and friends (Klopfer, Osterweil, and Salen, 2009). Whether they are playing on-line with peers or engaging with stand-alone games, players often connect with other players in order to improve their chances for success (Ito, 2006; Salen, 2007). Leveraging the premise that learning is an immersive process mediated by both social interaction and technology, researchers have begun to show how the design of games often encourages collaborative problem-solving due to their highly motivating social contexts (Gee, 2004).

Design Overview

Build-a-Tree is a puzzle game that encourages players to think about the evolutionary relationships among different kinds of organisms (see Figure 1). The game begins with players being tasked to construct a phylogenetic tree with two traits and three species (level 1). By the final level (level 7), players are challenged to construct a tree with six traits and seven species.

Build-a-Tree was designed around three core learning goals: (1) all living things on Earth are related because they share ancestors in common; (2) some kinds of living things are more closely related than others; (3) evolutionary relationships can be understood through shared inherited traits. The design has five major components—species tokens, trait tokens, branching tokens, a microscope, and visual feedback—all of which work in concert to provide players with the tools to construct scientifically-valid trees (see Figure 2).

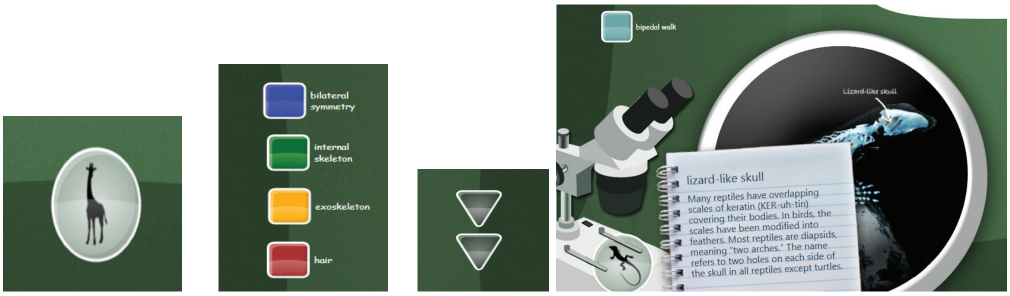

Figure 2: Major components of *Build-a-Tree* include (from left to right) species tokens, trait tokens, branching tokens, and the microscope.

Species Tokens: Circular tokens with silhouetted images of particular plants and animals are used to represent different species. Some of the species included in this game are bats, humans, dinosaurs, spiders, birds, frogs and crabs. In constructing their trees, players must group species tokens together according to the traits they share. Placement of species tokens is not fixed, meaning that players can experiment with their position in order to test ideas about relationships among the species.

Trait Tokens: Brightly colored square tokens are used to represent morphological and genealogical traits. Some of the traits included in the game are eight legs, internal skeleton, hair, bipedal walk, lizard-like skull, and exoskeleton. Players must position trait tokens in such a way as to ensure that particular pairs or groups of species inherit certain traits while others do not. Players can reposition trait tokens as many times as needed.

Branching Tokens: Grey triangular tokens are used to create branches. Branches represent the moments in time when species diverged from one another, inheriting traits advantageous to surviving in particular environments. Branching tokens allow players to create branches upon which they can place particular species tokens to indicate proximity or distance of species relationships.

Microscope: Not all traits are apparent by looking at the species tokens. Players can drag species tokens onto a microscope near the bottom of the screen. This reveals information about the species, including non-visible traits that it shares with other species. Most importantly, the microscope provides players with a visual representation of the traits in case they do not know what they are (Figure 2, right).

Feedback: There are multiple feedback mechanisms present in BAT. When players place traits and organisms on a tree correctly, green check marks appear on each species tokens after it has been assigned all of the correct traits. Players also receive gold stars, which help them track their progress through the game. Exclamation marks appear on species tokens to indicate that they are missing traits. Red X's appear if species have been assigned traits they do not have. The stars, exclamation points, and red X's, instead of a point system, allow players to experience both rewards and consequences for their actions in a non-punitive manner, making BAT a risk-free game that encourages experimentation.

Evaluation

We conducted a study in a natural history museum where we recruited parents and children aged 6 to 12 to try our game. Upon receipt of consent to be video recorded, parent-child dyads were assigned to one of three conditions: 1) 10-minutes of BAT gameplay followed by object-centered discourse; 2) 10-minutes of viewing of a video on evolution followed by object-centered discourse; or 3) object-centered discourse followed by either BAT gameplay or viewing of the video. To understand how game play might affect object-centered discourse, we gave each dyad a video camera and invited them to spend time looking at objects inside two exhibit display cases (Figure 3). These display cases hold a variety of animal specimens, fossilized dinosaur skulls, plant specimens, and marine fossils. Many of these objects overlap with the species depicted in BAT. We recently concluded our data collection and have a total of 20 parent-child dyads per condition, for a total of 60 parent-child dyads across all three conditions.

Figure 3: Parent-child dyads discuss objects that are in the exhibit cases above.

This study has three key goals: 1) to develop an understanding of the nature of parent-child gaming in museum settings; 2) to investigate whether gaming has an impact on object-centered discourse between parents and children; and 3) to ask how we might reimagine museum exhibit cases to integrate gaming experiences. The findings that follow focus on the first goal and highlight results from our preliminary analysis of game play between parents and children.

Findings

Here we briefly summarize our preliminary findings. We are using a grounded theory methods approach to analyzing the discourse taking place between dyads. Thus far, the data have revealed three key phenomena: 1) multiple interpretations of the rules of play; 2) player discussion of assigning colors to species rather than traits; and 3) shifting participation structures between parents and children due to their different sets of expertise. While we are still analyzing our data, it is becoming clear that these themes impact game play pathways and outcomes. For example, parent-child dyads are often explicit in their discourse about how they think BAT should be played.

Family 114A

Mom: Okay so what...Okay so we're just supposed to move things around…Alright Julie [drags bilateral symmetry token onto tree].

Daughter: Wait, don't move it yet mom. We have to work together.

Mom: Okay. Bilateral symmetry it showed. Alright. What should we move?

Daughter: What do you think? What about this one [points to and taps the plant species token]?

Mom: This one? [drags plant species token] Where do we want to put it?

Daughter: What about right in that circle [points to left side of the tree]?

Mom: [places plant species onto left side of the tree]

Here the child stops her mother from manipulating the tokens on the screen without her input, stating her belief that they are to work in concert to solve the puzzle on the screen. This short statement immediately influences their game play, with both the parent and child posing questions to each other about which tokens to move and where to move them. As the game play progresses, the child continues to make similar statements to her mother whenever she feels they are not co-constructing the tree, making clear her opinion that the game is to be played collaboratively and simultaneously. In contrast, some dyads exhibited a more asynchronous or solo playing style, taking turns manipulating icons or choosing to have one player manipulate the icons while the other player provides verbal or gestural input.

Family 134A

Daughter: It's your turn Mommy [sits down in chair].

[...]

Mom: You do it [does not touch screen].

Daughter: Mommy [stands up], you're supposed to like, I think, find how…[trails off, points at screen and waves finger at different parts of the tree] ok umm...[drags and drops cells with nuclei trait token onto tree, mom does not touch screen]

Here we see that the child in this dyad insists that BAT should be played through asynchronous turn taking. Furthermore, despite her statement to her mother that she should take a turn, the mother opts to have her daughter continue dragging and dropping tokens while she offers occasional advice. This leads to the child experiencing BAT as more of a single-player game rather than a multi-player one. As their game play moves forward, the mother becomes more involved, pointing to the screen and providing both verbal and gestural guidance to her daughter. These two small examples demonstrate that players' interpretations of the rules of play and their playing arrangements have consequences for the degree and type of collaboration between players as well as how they interact with the multi-touch display.

The second phenomenon apparent in the data is the variety of ways players discuss traits. Many dyads alternate between discussing whether a species needs colors or traits during their game play while other dyads more exclusively reference traits by their names *or* by their colors. See examples of this below.

Family 125A

Son: How about we switch the red and the green [referencing hair trait token (red) and the internal skeleton trait token (green)]?

Dad: There.

Son: But the bats aren't getting red [referencing hair trait token].

Dad: Then we gotta put this here [drags and drops hair trait token, assigning it to the bat species token].

Family 138C

Mom: Now this is bats and birds. Now look here. It says internal skeleton and hair [points to trait tokens]. So which one of these have hair [points to bird, bat, and human species tokens]?

Son: Um, this one has hair [points to bat species token] and that one's gonna go there [drags and drops hair trait token, assigns it to bat token].

Mom: Does this one have hair [points to human species token]?

In the excerpts above, the father-son dyad discuss how bats "need the red" rather than discussing that bats have hair. In comparison, the mother-son dyad do not reference color in their exchange and instead directly refer to traits by their proper names. Many questions have been raised as a result of this difference in trait discussion. Is there a difference in the learning outcomes between dyads that refer to traits as colors versus dyads that refer to traits by their name? When dyads refer to traits by color, are they using the symbology of the game only to infer the mechanics to "win" or are they assigning meaning to the representational forms to interpret and understand the relationships between species? Alternatively, are dyads doing a bit of both? It is our hope to answer these questions as they have clear implications for both the design of the game and outcomes for players.

The third phenomenon is the manner in which participation structures change between parents and children as they negotiate their differing and developing sets of expertise (game, content, or device expertise). This is made evident by each player's access to both the conversational floor and the interactional space. The conversational floor is defined as "an evolving, socially negotiated space in which one or more particular people are allowed to present conversational contributions to a discussion" (Engle, Langer-Osuna & de Royston, 2014 citing Clark & Schaefer, 1989). The interactional space is typically defined by visual salience and visual attention as well as how individuals affect each other's spatial access (Engle, Langer-Osuna & de Royston, 2014). Here, we focus on the latter aspect, the degree to which one player affects another player's spatial access to the display.

Family 114A

Daughter: Wait. I have an idea…that one could go there [drags and drops bird species token onto a different part of the tree], and that one could go there [drags and drops lizard species token where bird species token was previously located]. Wait [removes plant species token from tree]. And that one has to get a [starts to drag and drop lizard species token to another part of the tree]…

Mom: Oh, wait, what was that showing when you moved it [drags and drops plant and lizard species tokens]? Hold on, hold on [interrupts her daughter's attempt to touch plant species token]. It popped up a thing when we were movin' it [long presses plant species token].

[…]

Mom: So that...where else could that go...okay let's take [removes lizard species token from tree]...oh wait [puts lizard species token back on tree in same location]. Were we right [waits for visual feedback from game to gauge accuracy of tree]?

Daughter: Hmm.

Mom: Hold on [blocks daughter's attempt to move branching token]. Let's move one of the triangles Julie [removes branching token at base of tree and creates branches on another section of the tree]. 'kay [interrupts or ignores daughter's attempt to move bird species token] let's move this over here [drags and drops bird species token from one area of the tree to another]. Let's bring that one over to this side [daughter drags and drops bilateral symmetry trait token from one area of the tree to the other]. 'kay let go.

Daughter: What about [points to plant and/or lizard species tokens]...

Mom: Now put that over there [points to bird species token and points to an area of the tree; daughter drags and drops bird species token to where mother is pointing]. And bring this over here [mother drags and drops cells with nuclei trait token].

With this excerpt we revisit dyad 114A later in their game play and we note that the collaboration they exhibited at the start of the game has shifted as a result of the parent's developing expertise of the game mechanics. She blocks her child's attempt to access the conversational floor, which interrupts the idea her child is attempting to express. Furthermore, she limits her child's spatial privileges through verbal cues (e.g. "Hold on, hold on") as well as non-verbal cues (blocking and interrupting her daughter's attempts to manipulate tokens). It is possible that the mother's developing expertise is potentially constraining her daughter's opportunities to develop her own expertise, at least in the short term. This interpretation stems from the fact that the daughter's actions are a result of directives received from her mother rather than the product of any ideas the daughter is constructing about the mechanics of the game or the science content that is organizing the game structure. Parents often seemed to want to take on an "explainer" role and would spend some time leading the effort to explore the game mechanics.

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