Futura: Design for Collaborative Learning and Game Play on a Multi-touch Digital Tabletop

Alissa N. Antle, Allen Bevans, Josh Tanenbaum, Katie Seaborn, Sijie Wang
School of Interactive Arts and Technology
Simon Fraser University
Surrey, B.C., Canada
{aantle; alb19; joshuat; kseaborn; swa50}@sfu.ca

ABSTRACT
This paper introduces a collaborative learning game called Futura: The Sustainable Futures Game, which is implemented on a custom multi-touch digital tabletop platform. The goal of the game is to work with other players to support a growing population as time passes while minimizing negative impact on the environment. The design-oriented research goal of the project is to explore the novel design space of collaborative, multi-touch tabletop games for learning. Our focus is on identifying and understanding key design factors of importance in creating opportunities for learning. We use four theoretical perspectives as lenses through which we conceptualize our design intentions and inform our analysis. These perspectives are: experiential learning, constructivist learning, collaborative learning, and game theory. In this paper we discuss design features that enable collaborative learning, present the results from two observational studies, and compare our findings to other guidelines in order to contribute to the growing body of empirically derived design guidelines for tangible, embodied and embedded interaction.

Author Keywords
Interactive surfaces, tabletop games, multi-touch interaction, collaboration, educational games, simulation games, design evaluation, design rationale.

ACM Classification Keywords
H5.2. Information interfaces and presentation: User interfaces. K.3.m Computers and education: Miscellaneous.

General Terms
Design

INTRODUCTION
With the commercialization of the Smart Table and Microsoft Surface, digital tabletops are now being placed in informal (e.g. museums) and formal spaces (e.g. schools). Digital tabletops offer unique opportunities to facilitate collaborative learning interactions in such spaces. Simultaneously, research in the discipline of game studies has lead to increased interest in games for learning and education in both public spaces and more formal settings [9]. Educational games, if done well, promise to couple the intrinsic appeal of strategic play with a learning process. The potential to use the affordances of tabletop displays and multi-touch surfaces to support collaborative games for learning is compelling. Recent research publications in tangible, embodied and embedded interaction provides conceptual and empirical guidance for design to support collaboration (e.g. [6, 12]). Similarly, research in gaming has begun to explore new game platforms such as tabletops and whole body interaction (see [11] for a review). However, there has been little empirical work that explores the design space of multi-touch tabletop games for learning.

We had the opportunity to showcase a game for learning about sustainable development, called "Futura: The Sustainable Futures Game", at a 2010 Winter Olympics Celebration Site (Vancouver, Canada). The three pillars for the Olympics were Sport, Culture and the Environment. People often have misconceptions about what is involved to create a sustainable environment. Sustainable development planning is a complex problem. Choices and decisions often have lasting and unforeseen effects on the environment and the way people live and work. Sometimes, meeting the needs of both humans and the environment is not possible. The learning outcomes for Futura are not related to the learning of specific concepts (e.g. about ecology or urban planning) but instead our goal is to give players a chance to experience the tradeoffs and complexity involved in planning for a sustainable future. In doing so, Futura supports players to become more aware of the contradictory demands of maintaining environmental health and supporting population growth in an urban environment.

Our main research question is: What design factors are important to enable the kinds of interactions that support collaborative learning in a multitouch tabletop environment? We address this question using a design-based research approach which includes a design case methodology. The design case is comprised of theoretical underpinnings which inform our design choices; a detailed description of our custom tabletop and Futura learning game; a design analysis and rationale; and a summary of two observational evaluations. Our design rational uses theoretical concepts to argue for the importance of specific design features that support the kinds of interactions that provide opportunities for learning. The use of both theory and empirical data provides rigor to our design based research. We also compare and contrast our design choices with guidance from other researchers in order to contribute to a growing body of knowledge concerning collaborative learning in tangible, embodied and embedded interactive environments as conceptualized broadly by Hornecker and Burr [6].

THEORETICAL FOUNDATIONS

In this section, we present the four theoretical perspectives that inform our design-based research in collaborative learning through multi-touch tabletop games. In the Related Work section, which is located near the end of this paper, we compare our work with other design oriented studies of collaborative learning through tangible, embodied and embedded interaction.

Experiential Learning (Learning by Doing)

Learning is a process that leads to change in behavior or change in ways of thinking [9]. The theory and value of experiential learning is often attributed to Dewey. It was later popularized in the North American education system by Kolb. Experiential learning is the process of learning, or meaning making, based on a person's direct experience with some event or element of the world [8]. This approach to learning is often contrasted with rote learning and with didactic learning. However, experiential learning may be misconstrued since people may learn things other than what was intended from their experiences. For example, a student may learn from attending didactic physics lectures that they dislike physics, rather than learning that they dislike didactic lectures.

To support learning of intended outcomes from experience, a learning environment must provide the following four elements: concrete experience, support for reflection on that experience, support for formation of abstract concepts based on that reflection, and the opportunity to test or try out the new concepts through concrete experience [10].

Constructivist Learning

Many researchers are familiar with Piaget's stages of cognitive development. However, it is the stage independent aspects of Piaget's theory that are foundational to theories of constructivist learning. Forman and Pufall [4] provide an excellent overview of Piaget's influence on constructivist learning. Briefly, Piaget's theory of how learning occurs can be summarized with three concepts: epistemic conflict, self-reflection, and self-regulation. Epistemic conflict occurs when our ideas about the world are challenged by new perceptions from or about the world. Self-reflection is our deliberate and conscious attempt to understand a given situation through reflection. Self-regulation is our deliberate and conscious process of structuring, planning, reflecting and acting in order to resolve epistemic conflict and achieve what Piaget calls "equilibrium". It follows that a successful learning environment must provide physical and/or social opportunities for learners to experience epistemic conflict and resolve this conflict through support for self-reflection and self-regulation.

Collaborative Learning

Piaget's theory of cognitive development has been criticized for largely ignoring the social aspects of learning. When designing games for learning in public spaces, social interaction is likely and desirable. Therefore, collaborative learning theory brings important perspectives to social aspects of learning and must be considered in our work. In the computer supported collaborative learning (CSCL) literature, collaboration has been defined as "a process by which individuals negotiate and share meanings" and "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem" [14]. This differs from cooperative activities in which learners may coordinate their efforts, but the work performed is primarily individual [2].

CSCL theories outline three important elements required to support collaborative learning: objects of negotiation, referential anchors and support for meta-cognition. Objects of negotiation are shared external representations which can be modified by individuals or a group during the learning process [16]. Referential anchors are context-specific objects, utterances or gestures that support learners coming to common ground or understandings [1]. In a CSCL environment, referential anchors may be explicitly included through the use of digital representations. For example, the game status screens in collaborative digital games, which shows both individual and team progress, may serve as referential anchors. It grounds the players' communication in shared understandings of what has been achieved in the game, and what remains to be completed. Metacognitive processes that require support during group learning include monitoring, evaluating, and regulating individual and group understandings as they develop [3].

Game Theory: Microworlds, Simulations and Games

Educational technology and games researchers often distinguish between microworlds, simulations and games. Rieber [13] provides an excellent overview which we summarize here. *Microworlds* are a simple but complete model of a domain or system which enables a person to "live" in that domain for some period of time. Microworlds are accessible to novice users but support advanced exploration. In order to be accessible a learner must know immediately what to do within a microworld. For example, a natural microworld is a sand box. A child, with a bucket and shovel, can explore density and volume. It is often assumed or expected that learners can and will self-regulate their learning in a microworlds. This may occur when learners are motivated, take responsibility for goal setting and planning, and actively structure the learning to suit their own style. While self-regulated learning is effective, it is difficult to know how to design an artificial microworld to support self-regulated learning.

A *simulation* is a high fidelity model of some domain; and as such it may not be suitable or accessible to novice users [13]. An advantage of simulations for learning is that they provide direct access to subject matter or content which might not be readily accessible in the real world. A key assumption behind simulations is that users will "learn by doing".

Digital games have recently been used for instruction. Kirriemuir and McFarlane provide an excellent overview which we draw on here [9]. Digital games provide visual digital information to one or more players, take input from players, process that input according to a set of programmed game rules, and change the digital information displayed back to players. A defining characteristic of a game is the set of game rules. Developers of educational games have hoped to harness the motivational power of games to provide motivation for learning.

FUTURA: THE SUSTAINABLE FUTURES GAME

In this section we outline our design goals for Futura, and describe the system implementation, game overview, and user interface. We follow this section with a design analysis of Futura through the lenses of learning and game theories.

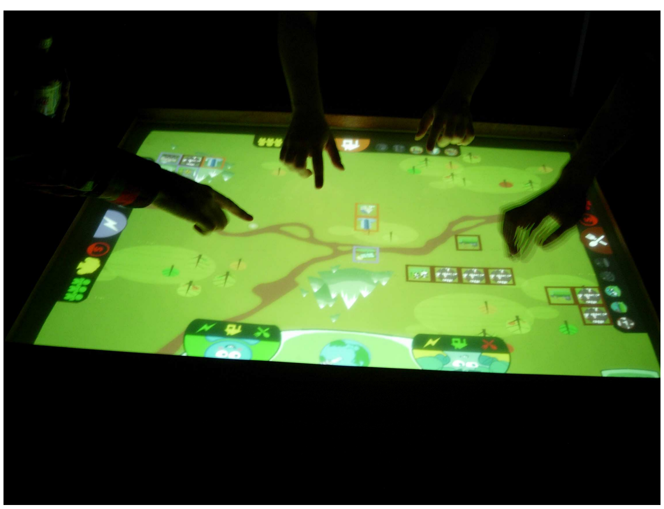

Figure 1. Futura interactive multi-touch tabletop

Design Goals

Futura was created in order to explore the novel design space of collaborative, multi-touch tabletop games for learning in public venues. We require players to be able to read simple texts and so the target audience was seven years old and above.

The main learning goal was to support people to improve their understanding the complexity of sustainable development. This goal applies to both children, who may know little about sustainable development, and to adults, who may be well read on the topic. We are interested in helping players improve their understanding of the importance and difficulty of achieving sustainable development through active participation in a simulated land use activity. We are not trying to teach concepts related to sustainable development. Our focus is on participation and simulation, which is in line with recent trends in research on pro-environmental behavior that suggests that providing people with information about issues of public concern is not sufficient to change their behaviors. Rather, people need to participate through various mechanisms in order to shift their awareness or understanding of the importance of change which in turn may lead them to engage in desired behavioral change [15].

Our secondary design goals were to create a tabletop game for a 2010 Winter Olympics Celebration Site that encouraged people to walk up and play together, and to create a game that was accessible to a wide range of ages.

System Implementation

Futura is run on a custom digital multi-touch tabletop (Figure 1). Our system is housed in a modified IKEA wood and metal table with telescopic legs and a custom metal undercarriage which supports the camera, PC and projector hardware. The surface of the table's wood frame supports an Endlighten™ acrylic surface. Our sensing system relies on a diffused surface illumination (DSI) technique with four infrared strips, one on each side of the rectangular surface. We capture touches with a single web camera with an infrared filter on a wide angle lens embedded in a custom mount. The camera can cover an active sensing area of 85 by 68 cm. The camera is connected to a PC (Intel Core2 Duo 2.66 GHz processor) with a firewire cable and provides 30 frames per second (fps) data capture. We process camera data using Community Core Vision, an open source finger tacking software. The game application is written using an existing C# multi-touch library called "Breezy" that takes TUIO input and provides multi-touch user interface components. A single short-throw projector provides 1024 by 768 resolution on the output surface of 103 by 68 cm. We use a velum mat, attached below the Endlighten™ acrylic, for the projection surface, leaving the top surface of the acrylic exposed, which results in better touch tracking.

Game Overview

Futura is a game in which players directly participate in a fictitious, yet realistic, land use planning process. Futura is a simulation that takes place in a microworld river basin derived from a map of the Fraser River basin surrounding

Vancouver, Canada (see Figure 2). Land use planning is a challenge that needs to be solved by many people working together. In Futura, players take on the role of important decision makers, responsible for providing people with food, shelter, and energy for the region. Each player must meet the growing population's need for their resources (food, shelter and energy). Each player is responsible for his or her own individual play, but all the players must work together in order to succeed, much like real-life decision makers.

Players of Futura have to learn how to meet the needs of an ever increasing population in the game world without endangering the health of the environment. They do this by dragging and dropping tokens representing facilities such as: energy facilities (e.g. solar energy), shelter (e.g. single dwelling, townhomes), and food production facilities (e.g. high productivity livestock, organic produce), onto the map. However, they can only place facility tokens if they have enough money which accumulates as time passes.

Figure 2. Futura user interface

Multi-touch interaction enables the kind of fast paced activity required to provide for the growing population while time quickly passes. Players can also touch facility tokens in their toolbar to learn more about them through displayed information cards. They can drag facility tokens onto the map to "build" them. If they are not careful, the choices they make can have serious consequences. The short duration of the game compels players to act while giving them opportunities to see how their decisions affect the world over time.

The individual scores of the players are combined into a single global impact score for the environment and the population, which are displayed in the global display and reflected in the map colour. Players win the game if they can meet the needs of both people and the environment. A video is available under "Videos" at http://www.antle.iat.sfu.ca/Futura/.

User Interface

The main interface is an interactive map which is augmented with three player toolbars and a global information display about the state of the world (Figure 2). The player toolbars are located on three sides of the interface (see Figure 2, left, bottom and right). There is a toolbar for each of three resources: food, shelter, and energy. Each toolbar contains facility tokens for its resource type (left side of toolbar), and information displays for money, environmental impact, population status (right side). For example, the energy toolbar has facility tokens for fossil fuel, bio-diesel, wind energy, solar energy and a clean energy research centre. The global information display is located at the top of the map (Figure 2). On the left side is a tree character which shows the state of the environment (Figure 3). On the right side is the population character which shows how well the growing population's needs are being met. The rest of the interface contains the microworld map and facilities that have been placed on the map through player actions during the game. The map changes its background colour from green to brown if the environment deteriorates, providing ambient feedback (Figure 4). The mood of the audio track also changes to reflect the world state.

Figure 3. Global environment character: 3 states

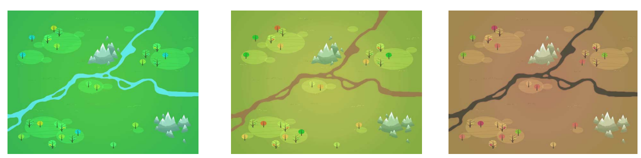

Figure 4. Ambient world state feedback

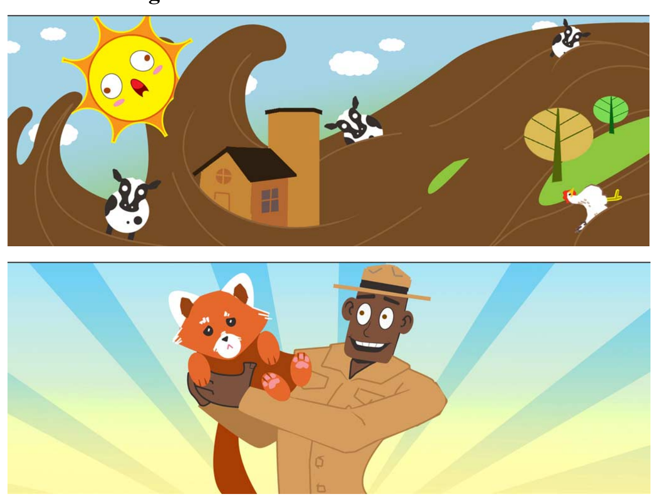

Figure 5. World events: mudslide (top), species saved (bottom)

During game play, world events pause the game and depict either a positive or negative world state (Figure 5). The game concludes with a final screen showing the state of the environment and population, and providing hints for future play. The satellite icon (top, Figure 2) can be used to access the game control menu that includes pause and, restart function, and an instructions/help feature.

DESIGN ANALYSIS AND RATIONALE

We now analyze Futura through the lenses of learning and game theories focusing on how specific design choices and features enable interactions which we have identified from theory as beneficial for learning.

Ludic Challenge, Motivation and Self-Regulated Learning

Each Futura game is very short; only three minutes long. In three minutes about one hundred years pass in the microworld. Multi-touch interaction combined with a persistent style game provides ludic challenge, which in turn fosters motivation to win the game. The game is challenging. It is difficult to win the first time. All of these factors work together to create a game that is exciting, engaging and supports repeat play which provides opportunities for learning. The repetitive and goal directed nature of the game combined with ludic challenge provide motivation and mechanisms for *self regulation* of *metacognitive processes* related to thinking, feeling, behavior, and attention which facilitate learning from play.

Learning through Experience: Win or Lose

Futura is designed to facilitate players to *directly experience* the complexity and difficulty of balancing environmental and human needs in sustainable development. The tabletop size and form enable a multiplayer game which blends features of digital games, simulations and microworlds, as suggested by Rieber [13]. Losing the game advances the learning outcomes since players directly experience the difficulty of balancing environment and population. This is true even if players only play once. Players win once they begin to understand the complexity of the problem and develop strategies to address it. This design strategy is in line with experiential learning in which players learn from a concrete experience, and then test out their ideas through their continued experience of playing the game. The result is a multiplayer, simulated microworld game that resembles stakeholder driven urban planning and enables opportunities for experiential learning whether players win or lose.

Balancing Individual and Group Play

Sustainable land use planning is a problem that needs to be solved by many people working together. An early design decision was that players would take on the role of important decision makers, responsible for providing people with food, shelter, and energy for the entire region. The tabletop form supports each player to literally take a "side". Each player is responsible for his or her own individual play, but all the players must work together in order to succeed, much like real-life decision makers. The size of the table and interface design precludes one player from taking over the game. It is physically not possible to reach all the toolbars from one position. These choices, enabled by the tabletop form and interface design, provide opportunities to learn through a *collaborative process*.

Reflection and Action in Knowledge Construction

Futura's challenge level was designed so that most groups of players would lose the first few times they played. From a constructivist perspective, we intentionally use game challenge to introduce *epistemic conflict*. From this starting point, we designed the game rules so that in order to get better at playing, players must also get better at thinking about the challenges of sustainable development. To facilitate this kind of thinking, there are various design features that explicitly support opportunities for *reflection* and *self-regulation*. These occur both during continuous action and in discrete pauses or breaks in game play.

The changing map colour provides ambient feedback continuously during play. There are also discrete opportunities for reflection. For example, players may pause the game at any time with the satellite button. The world events (e.g. mud slide) also pause the game, providing both a *reason* and the *time* to reflect. The end of game summaries provide feedback about how well the group did and provide some advice on how to do better in the future. These design features provided players with opportunities to break from the fast-paced action enabled by multi-touch interaction and reflect on their decisions and choices as they actively construct knowledge.

Learning from Others

The interface allows all the players to see how and what their co-players are doing. Each player's toolbar contains resources that any player can drag and drop onto the map. Successful collaboration relies on toolbars as *objects of negotiation*. The three sided interface design ensures that each player can see what the others are doing, and can help others by reaching over to another's toolbar. This provides opportunities for each player to learn from and help others, and in doing so, help the group succeed.

Providing Common Ground

Winning the game requires coordination among a potentially diverse group of players, from young children to the elderly. The overall game state is reflected in the changing map colour (green to brown), which should be easily understandable by novice players. The global information display at the top of the table is more complex and supports more advanced players. In both cases, the feedback serves as *referential anchors* because it changes as the game proceeds and provides common ground for shared understandings. This multi-layer feedback design enables players of all abilities to understand what is happening and what is needed and thus supports collaborative meaning making across a broad group of users.

OBSERVATIONAL STUDIES

Study Design

We had two opportunities to conduct observational design studies of Futura in informal settings. The aim of both studies was to observe Futura in use and collect data in order to explore how our design decisions impacted interactions which in turn create, shape or constrain opportunities for learning.

Futura was presented at the 2010 Winter Olympics. In this field study, we observed hundreds of users of all ages and nationalities using Futura. People queued to play and were given a brief introduction to the game by a volunteer using an instruction screen. Players often formed impromptu groups with friends or family. They were allowed to play as many times as they liked, depending on how long the queue was. We also presented Futura at a Simon Fraser University Open House. We have no numeric demographic data for the Open House participants because we focused only on informal observations. We collected field notes that included descriptions of behaviors and quotes from players. We analyzed our observational data using open coding to search for repeated patterns of verbalizations and interactions. The final themes we present were identified independently by two more of our researchers.

Study Results

We will focus on those results that help us identify and understand how design features enable attitudes and interactions that support opportunities for learning.

General Attitude to Futura

In terms of broad attitudes, many participants expressed enthusiasm about playing Futura. They liked crowding around the tabletop form, and enjoyed the retro-style cartoon graphics. One player said that Futura "… was easy to play but hard to win."

Learning about the Complexity of Sustainable Development

Most participants who talked about what they learned commented that keeping the planet healthy was difficult. Some participants verbally noticed the relationship between facility costs and environmental impact (e.g. cleaner energy facilities cost more). We did not hear participants verbalize that they learned any new specific knowledge from the game or information cards. However, it was not our goal to "teach" specific things related to sustainability concepts, but rather to enable a shift in awareness about the complexity of the issue. Our observations show support for the achievement of this goal.

Fun, Serious Play and Narrative

Players' affective responses while playing Futura varied tremendously. Children and teenagers seemed to express a sense of having fun more that adults. An older child commented that it was "Challenging … which made it really fun to play". Conversely, many adults seemed intimidated by their first round of play. They would generally play more "seriously" if they played subsequent rounds. A noticeable exception was adult women who were playing with (their) children. These women seemed to have more fun than adults in groups without children.

Many players created meaningful narrative around game events. For example, when the world map would change colour (usually for the worse), players would comment about their population dying, or water becoming scarce in their world.

Working Together

During the first play, much game-related talking between players was related to interface instructions. For example, "We need more farms" or "Press harder" or "Try this [token]". The most consistent form of coordination was during facility placement. Many players also talked to each other about where to put certain facilities on the map or where to place new facilities in relation to tokens that had already been placed. This is interesting since the game does not yet incorporate spatial location data into the simulation model.

In groups composed of parents and children, resources were often shared and discussed by two or more players. Parents would often reach over and point out, or physically drag out, a resource for their child. Some parents triggered information cards for their child's facilities while explaining why they should or should not use that facility at a particular time in game play. Other group configurations also helped each other. In a group with all teenagers, one player commented that they learned from working with other players … "That if you work together, it's easy to help." Another said, "You get much more help so you can achieve better goals and you can explain each others' ideas to get the world a better place."

Players who played the game more than once often began to talk to each other about how the environment and population were doing, and would work out strategies to keep the global indicators green (i.e. healthy). In situations with more than three players, there was often some discussion among players on the same team about which tokens to place next to win the game. In groups that played more than once, they often switched roles. "I want to be energy this time."

Understanding Multitouch Interaction

Since the touch-and-drag actions to place facility tokens and touch-and-hold actions to trigger information cards were usually explained to players before they started, most players did not seem to have difficulty understanding how to interact with the table. We observed many players, usually children or teens, simply walk up and touch the table. If the main start screen was active, then a player would often simply touch the large start button to begin the game. Once the game started, they often touched different areas of the interface before they discovered that the toolbars had facilities tokens that could be moved onto the map. Once they were shown or discovered how to move tokens onto the map, they progressed quickly.

Multitouch Tracking Issues

We observed some touch tracking issues which interfered with players' ability to smoothly interact with the game. For example, we noticed a "small finger problem" with some children who then resorted to using their fists. We also found the tracking system did not perform well on the Olympics site when the sun was high overhead, despite the tent covering the tabletop. To ensure optimal tracking, we limited the play hours to 4 pm and later when the sun was low in the sky. Some players who had issues with the system not registering their touch often tried touching harder or dragging more slowly and deliberately. Most did not give-up. However, we observed that tracking problems shifted players' focus from what was happening in the game, to the immediate task of trying to get a facility token onto the map, or trigger an information card.

Understanding the Interface

Players readily understood that their role required them to use their toolbar to place facilities and quickly realized that the facilities tokens could be moved onto the map. Players often tried to drag the money or population or environment indicator icons from the toolbars onto the map. A few players wondered aloud about what the global indicators meant, and what they were supposed to do in response. Few of the players understood the relationship between the individual toolbar indicators and the related individual status indicators on the global display (Figure 3). However, most were able to understand the local toolbar indicators, and the global environment and population indicators that reflected the cumulative game state.

Some players began to question and think about why the map was turning from green to brown and the global environment tree indictor to red. One said, "Look, the tree is turning red! Look the world is turning brown. What's happening?" While many players were able to determine what was happening and how to rectify the situation, some did not (e.g. "It was fun and I got to learn. But confusing!")

The world event screens (Figure 5) seemed to be easily understood. However many players expected these events to alter the game world (e.g. the mudslide event should results in players losing money). Players rarely expressed confusion with the end state screens. We observed that some players read the explanatory text aloud, especially if they were with a larger group of friends or family. Some players discussed which tokens or team members were responsible for the game end state. Others showed evidence of using the feedback to determine how they could improve their play for the next round.

Repeat Play

Just under half of the subjects played the game more than once. This was affected by how long the queue was and group configurations. At the Olympics site, we observed that many of the repeat players were pre-teens or teenagers. Groups of teenage event volunteers would often play multiple times during breaks, attempting to win the game or loose spectacularly.

We observed a temporal pattern when groups played repeatedly. Players often started out very focused on their own toolbar and played independently. After they lost, they began to give more attention to what other players were doing. After several plays, many groups shifted to not only be aware of others' actions but explicitly work out strategies together. For example, a group placed a few high yield facilities from each resource type early in the game and then countered the negative environmental impact by placing as many clean facilities as each of their money reserves would allow. This shift from an individual to group focus most often lead to winning strategies.

COMPARING TO RELATED WORK

Hornecker and Buur [5] introduce guidelines associated with supporting embodied facilitation. Embodied facilitation refers to how physical spaces and structures determine, constrain and direct user interactions which in turn shape how users collaborate. Embodied constraints restrict what people can do and make some behaviors more probable than others. In the Futura design, the assignment of toolbars to three sides of the table encouraged individual player roles but did not stop one player from reaching over to help or take control from another, both of which may contribute to the need for negotiation and subsequent coordinated action. Multiplayer game play was facilitated by the spatial structure of the tabletop and interface design rather than the traditional game design approaches of using turn taking or identification of tokens with specific users. This approach also eliminated the need to track individual players, which is difficult in a walk-up-and-play environment. The design was flexible: it encouraged intended role play without eliminating other ways to play. Thus we neither explicitly support nor constrain sharing of resources but rather designed to afford individual actions as part of group play and leave opportunities for emergent forms of group interaction.

Price et al. discuss opportunities for reflection and action during a study of students exploring optics with a tabletop TUI activity [12]. They suggest that the combination of visual feedback on the tabletop with both discrete actions (e.g. placing TUI objects on the surface) and continuous actions (e.g. dragging and dropping) enable acting and opportunities to reflect on the consequences of that action. In their system, reflection and action are intertwined. In Futura we provided opportunities for reflection *during* continuous action in a similar manner. We also provided opportunities for reflection *apart* from action such as the world events that pause the game and provide a reason to reflect and discuss what was happening in the game. Reflection *during* action was largely an individual activity since a player's attention was likely on their actions and thinking about the results of these actions. Reflection *apart* from action was a collaborative activity. In this way, the

Futura design supports both individual and social knowledge construction. We present our design as an alternative approach that can facilitate the kinds of interactions that support the interweaving of reflection and action.

Hornecker et al. also introduce the theme of designing to support lightweight interactions [7]. They suggest avoiding sequential interactions or predetermined territories because they may interfere with fluent interactions. Territoriality is of particular interest since we neither fully promoted nor inhibited a shared environment but supported flexibility of interaction. Because Futura required collaboration to win, negative interference between players was discouraged by the adverse affects it had on group outcomes. We suggest that the use of sharable individual and group territories balances structure and flexibility which supports emergent learning opportunities for a broad audience. We suggest this approach as an alternative to light weight interactions.

CONCLUSIONS

We presented the results of our design-based research which explored the novel design space of collaborative, multi-touch, tabletop games for learning. Using theoretical concepts and observational findings, we identified several key design features. These include using multi-touch interaction on a large surface to create a real-time simulation game world; using the spatial structure of the tabletop to support players to take roles ("take sides") but not allow a single player to take over the game; using discrete world events to pause fast-paced multi-touch interaction in order to facilitate reflection and self-regulation; and using spatially separate but sharable individual territories and resources to facilitate negotiation and learning from others. Our study results indicated that Futura was effective and enjoyable for well over half the general public who walked up to play. We suggest that our design can serve as an exemplar of design features which enable collaborative learning through game play on a digital tabletop.

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