Youtopia: A Collaborative, Tangible, Multi-touch, Sustainability Learning Activity

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ABSTRACT

Youtopia is a hybrid tangible and multi-touch land use planning activity for elementary school aged children. It was implemented on a Microsoft Pixelsense digital tabletop. The main method of interaction is through physical stamp objects that children use to "stamp" different land use types onto an interactive map. Youtopia was developed to investigate issues surrounding how to design and evaluate children's collaborative learning applications using digital tabletops. In particular we are looking at how the interface design supports in depth discussion and negotiation between pairs of children around issues in sustainable development. Our primary concern is to investigate questions about *codependent* access points, which may enable positive interdependence among children. Codependent access points are characteristics that enable two or more children to participate and interact together. In Youtopia these implemented through sequences of stamps that are required for successful interaction, which can be assigned to children (codependent mode) or remain unassigned (independent mode).

Categories and Subject Descriptors

H.5.m. Information interfaces & presentation (e.g., HCI): Misc.

Keywords

Tangible computing; multi-touch interaction; digital tabletop; sustainability; positive interdependence; collaboration; children.

1. INTRODUCTION

Youtopia is a tangible and multi-touch tabletop land use planning activity implemented on a Microsoft Pixelsense (Surface) table. The Youtopia tabletop application enables elementary school aged children to use physical wooden stamps to "stamp" land uses onto an interactive map, as well as use multi-touch (like an iPad) to interact with the land use planning map. The goal is to provide children with a chance to experience the challenges of balancing environmental and human needs in terms of food, shelter, energy and pollution. short video of Youtopia functionality is available at www.antle.iat.sfu.ca/Youtopia. In this paper we focus on our design-based research approach as context for the demonstration of our prototype, Youtopia. We present our research motivation, research question, system description and implementation details.

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We begin with an overview of our previous two related prototypes. Based on a series of studies with these previous prototypes, we identified a knowledge gap. This gap was used to formulate a new research question, which in turn was then used to drive the design of our new research prototype, Youtopia. For more information see [1, 3, 4] for detailed *Related Work* sections on collaborative and tangible learning design for children, and look for an upcoming paper on our experimental results.

2. MOTIVATION

Youtopia is our third tabletop application developed to explore research questions focused on the design of games for learning, tabletop support for collaboration, and tangible and multi-touch tabletop interaction. In each prototype we have focused on the topic of sustainability and related visual-spatial activities which are suitable for the study of collaborative learning on tabletops. Our original prototype, called T*owards Utopia*, was a single player tangible tabletop sustainable land use planning activity implemented on a custom digital tabletop [4]. We ran an exploratory study with 30 children aged 7 to 10. We evaluated learning using a teacher to conduct clinical interview style pre and post tests based on key concepts in sustainable land use planning taken from the British Columbia (BC) curriculum (Canada). Our results indicated that children showed a significant improvement in understanding of the key concepts at the $p < .001$ level. We also documented different learning and interaction theories that we used to inform our design.

Our second tabletop land use planning game, *Futura*, was a collaborative multi-touch tabletop sustainable land use planning activity implemented on a custom digital tabletop [1, 2]. We ran a study at the Winter Olympics to study issues in collaborative games for learning. In addition, we built a second version with two "world state" visualization tools implemented using a multi-touch and a tangible approach. Comparison of groups' use of the tools revealed that the physicality of the tangible tools supported a higher degree of individual ownership and verbal announcement of tool use, which in turn supported group and tool awareness [14]. The two Futura studies enabled us to identify unsolved challenges and contributed to the development of our design guidelines for collaborative tabletop games for learning. In parallel, some of the theories we found relevant for designing tangible and multi-touch tabletop learning were formulated as actionable design guidelines and appear in [3]. In that paper we also identify areas that require further research.

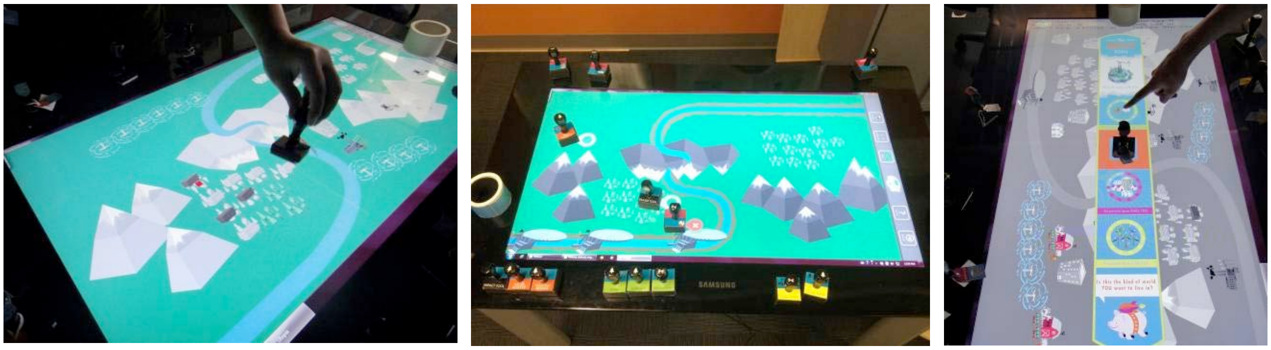

Figure 1 (a) Stamping trees into lumber (b) Groups of related tree & wrench stamps (c) World state stamp & food circle touched.

Our third and new prototype, Youtopia, which is the focus of this paper, was created to address a key research question about designing to support effective collaboration based on the combination of this previous work. In summary, the core issue was that the multiple access potential of TUIs may be designed to support multiple users interacting simultaneously. However, this alone does not ensure collaboration [5, 10]. To avoid parallel independent play, learning designs can require either simultaneous or accumulation of multiple actions to trigger digital events [3]. This can support collaborative activity since the coordinated action of more than one child is needed to successfully enact a strategy [6]. Research was needed to determine when such an approach influences interactions between children (e.g. when do codependent access points support children in productively negotiating with each other around what they want to achieve?), and if such interactions provide benefits to learning [3]. Our primary research question is: Does creating opportunities for positive interdependence through *codependent* access points promote negotiation and collaboration rather than parallel independent play?

3. BACKGROUND

Collaboration can be defined as “a process in 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” [13] (p 70). Collaborative tasks create positive interdependence in knowledge, tools and/or skills among children and requires the coordinated activity of multiple children for success [10]. Access points in a TUI system are characteristics that enable a child to interact, to participate and join a group’s activity [8]. While TUIs enable several children to actively use the system at the same time, previous non-TUI research has shown that this often results in a non-collaborative situation of parallel play [9]. It is unclear when a TUI that supports multiple simultaneous users will enable effective collaboration. Hornecker suggests that a constrained input system (e.g. limited number of access points) may require sharing and coordination [7]. However, Marshall *et al.* found that a limited number of access points can also lead to competitive behaviors [11].

We suggest an alternative design. In Youtopia we have created a multi-user system in which the inputs are codependent; that is they are sensed individually, and the system responds to them collectively. Thus, each child in a pair needs to take specific actions in order for the system to respond in the desired way. For example, new housing can be built only if trees are first converted to useful lumber, and then housing is placed in a suitable location. This strategy may support situations of positive interdependence in collaboration since the task requires the coordinated action of more than one child to enact the strategy. Children must negotiate and reconcile what they want to achieve to succeed. However, studies of interaction with multi-user tabletops in the field have suggested that even coherent groups of users may not immediately work together on collaborative applications [12].

We examine the above research question through our implementation of tangible stamps and an interactive tabletop map based land use planning task. To successfully build human developments (e.g. houses, farms, coal plants) requires sequential use of natural resource stamps followed by human development stamps. That is we have implemented a codependent access point scheme. Successful interaction requires two or more codependent stamps to access the system. At least two stamps tools must be used in sequence to result in successful building of developments. To support positive interdependence under this scheme we can then assign one group of stamps tools to one child (designated the natural resource planner) and another group of stamp tools to the other child (designated the developer). One stamp from each group is required for successful interaction. This distribution of stamp tools may create positive interdependence between children during the task. We will explore if this configuration (codependent) promotes effective negotiation and collaboration rather than parallel independent play. We compare this configuration to one in which each child can use any stamp (independent).

4. YOUTOPIA DESCRIPTION

Youtopia was designed to meet basic BC (Canada) learning outcomes for grade 5 environment and sustainability topics (ages 10-11). Sample learning outcomes include:

- Analyze the relationship between the economic development of communities and their available resources;
- Analyze data to determine if a resource is renewable or non-renewable;
- Understand that some resources are constantly available and are considered to be renewable resources (e.g. hydropower);
- Describe potential environmental impacts of using living and non-living resources;
- Analyze how living and non-living resources are used.

The main activity in Youtopia is using physical stamps to designate land use types on an interactive map (Figure 1a). The goal of the activity is to support either a small or large population with enough shelter, food and energy without over polluting the world. There are different types of shelter, food and energy sources as well as nature reserves, each with different benefits and limitations. The map is of a small area of land including mountains, valleys, grasslands and a river. The game begins by

Figure 2 (a) Error tab appears (b) pulling tab reveals error message (c) message may be resized or rotated so other child can read.

default with a small population and default map. There are four maps that have similar size and resources. Only the terrain elements are arranged differently. Choosing a new map by touching the maps symbol on the menu restarts the game. Choosing a large population by touching the population symbol on the menu continues the same game with a larger population or restarts depending on which is selected. Together, the different populations and maps add sufficient complexity to the application that children can play for long sessions.

Natural resource and human developments are two main land use categories. They are designated with a tree or a wrench on the top of the stamp handle. Each is also labeled with a picture and text to designate the land use type. When stamped in a legal location a larger version of the picture on the label appears on the map. Six stamps can be used to designate natural resources as usable for subsequent human development (e.g. create coal mine from coal reserve, harvest lumber from forest, create river reserve). Seven stamps can be used to designate human developments made from usable natural resources (e.g. create coal plant from coal mines, create house or townhouse from lumber). To help children understand the relationships between the natural resources and their associated developments, the stamp tags are labeled and displayed with like colours. For example, irrigation, farms and garden stamps are all colour coded green (Figure 1b).

A child must stamp or designate a natural resource as usable before a shelter, food or energy development that requires that resource can be stamped. For example, since developments like the farm or garden require water from irrigation, irrigation must first be placed on the map adjacent to the river. However, the river's water levels can be depleted so developments that depend on its usage may be limited due to this constraint. Farms require more irrigation than gardens but produce more food. Building any development requires codependent access through the stamps since it is a two step process in which a natural resource must be designated for use, and then a related human development placed in a suitable location. When natural resource stamps are assigned to one child, and development stamps to the other, a situation of positive interdependence between the two children may result. We call this the codependent mode because both children must take action before anything can be built on the map. For example, one child must stamp an area of forest usable (i.e. turned into lumber) before the other child can use their shelter stamp to build housing. Thus, creating any kind of development depends on each child taking action in a coordinated and collaborative manner. We expect that the pair will work together repeatedly to decide which natural resource to use, then the natural resource child will use a tree stamp to designate resource use, then they will decide where to place the development that uses that resource, and then the developer child will use a wrench stamp to create the development. In the *independent* mode, stamps are not assigned and either child may use any stamp. However, specific sequences of stamps (turn forest into usable lumber then build housing) must still occur for successful interaction. We will compare codependent and independent tool assignment conditions to investigate how each affects positive interdependence between the children during the task. Youtopia supports both conditions depending on how stamp tools are assigned.

If a child places a stamp in an illegal location then one of five types of error tabs will appear (Figure 2). For example, if the hydroelectric dam is placed on the river but there isn't enough water left (because there are already one dam, irrigation, and three river reserves), then the "resource used up" orange tab appears (Figure 2a). A child can use their finger to drag the feedback tab away from the stamp to display a message (Figure 2b). Messages are focused on explaining land use relationships and providing information on corrective action. A child can also resize (Figure 2c) or rotate the message so that the other child can see it.

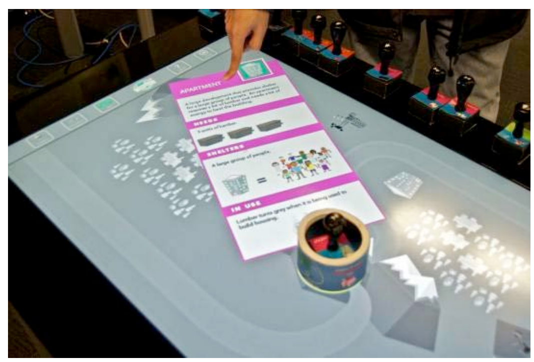

Figure 3. Information "ring" tool.

There is a third set of tools that include: erase, information, and impact. These tools can be used by any child in both conditions. The impact stamp tool shows the current state of the world in terms of what percentage of the current population has its need for shelter, food and energy met, and how polluted the world is (Figure 1c). Once the impact tool is placed, the map is frozen and either child can use fingers to touch one or more of the shelter, food, energy or pollution circular displays which then highlights on the map all of the resources and developments that contribute to that state (Figure 1c). The circular ring tool provides information about each stamp. Placing a tree or wrench stamp in the ring results in the display of information about the relationships between that and other stamps as well as information about constraints on usage and location of that stamp. For example, placing the apartment stamp in the ring provides information on the amount of lumber required to build an apartment and how many people it supports (Figure 3). Information is provided both textually and pictorially. When the ring tool is in use, the map is frozen and greyed out, so that the other child cannot continue to interact at that time.

5. SYSTEM IMPLEMENTATION

Youtopia is implemented on a Microsoft commercial PixelSense (Samsung SUR40) digital tabletop running Windows 7 operating system. The surface is comprised of many individual infrared sensors which act as a camera. These sensors are integrated within the LCD panel. The screen has a resolution of 1920 x 1080 pixels.

Youtopia is developed with C# using the XNA framework and the standard Microsoft Surface 2.0 SDK. The main development environment is Microsoft Visual Studio 2010. There are several systems for handling various tasks including menus (touch), stamp inputs (tangible), two types of tool inputs (tangible), error feedback tags (touch), and system logging (non-interactive).

The SDK recognizes: fingers, blobs and tags. The Youtopia system uses all three of them. The tags are used for the thirteen natural resource and human development stamps. Each stamp triggers an algorithm that checks if its placement is legal given the current state of the game. If the stamp is a legal move, then an image representing the stamps' land use type appears. If it is not, then one of five types of error feedback tabs occur (Figure 2). Each tab is colour coded and has a symbol to designate the error type. Errors include: wrong location, not enough resources, space already full, etc. At any given time, the state of the world stamp can be placed. This stamp freezes the map and displays status rings and text for pollution, shelter, food and energy. Touching each status ring highlights all the resources and developments on the map that contribute to that state (Figure 1c). There is also an erase tool stamp. The third tool is a ring into which any stamp can be placed (Figure 2). Blob tracking is used for the circular information tool. Fingers are tracked for interacting with the main menus and error tabs that appear when stamps are used incorrectly.

All system parameters are stored in spreadsheets, which are comma separated value files. For example, the number of lumber units required to build an individual house, townhouse or apartment are specified in the spreadsheet as well as the percentage of the population each housing style accommodates.

6. CONCLUSION

Youtopia is a novel hybrid tangible and multi-touch tabletop activity designed to address unresolved issues in interaction design for children. We will investigate how a codependent tangible tool access scheme may be used to support effective collaboration. In one condition tree stamps will be assigned to one child, and wrench to the other child in a pair. In this condition both children need to participate to complete the task. In another condition, stamps are not explicitly assigned to either child. In this case, children may work together but it is possible for a single child to control codependent stamp sequences. Future experimental work will investigate these two scenarios of use in order to see how each affects collaboration.

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