An Application of Tangible Interfaces in Collaborative Learning Environments

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1. Introduction

Over the years, educators and government officials have searched for ways to improve learning in our schools, particularly in the areas of math and science. Many have come to recognize that collaborative activities, learning through play, and teacher guidance can help children to get over their initial fears and even begin to enjoy these subjects. Yet, at the same time, shrinking school budgets are making it harder to support these approaches to learning. Tangible Interfaces for Collaborative Learning Environments (TICLE) was conceived in response to this need [Scarlatos 2002].

TICLE embodies a different notion of support for collaborative learning. It supplements physical learning activities with computer tutors that ask relevant questions when the students get stuck. With TICLE, a group of children is given a set of physical puzzle pieces and a specific goal (such as "put these shapes together to make a square") designed to teach some math or science concept. As the children work with the puzzle, a computer system observes their actions. This system encourages the group as they make progress, and offers to give them "hints" when they don't. The hints take a scaffolding approach, asking the children to consider smaller related problems.

The advantage of TICLE is that students are allowed to focus on solving the puzzle without having to worry about how to give instructions to a machine, or whose turn it is to use the mouse. Yet they may also turn to the computer for help and further information if and when they need it. TICLE is unique in that it

1) makes the computer take on the role of "guide on the side" without dominating the educational activity,

2) allows the students to work in groups on physical learning activities, without having to learn a computer interface, and

3) prescribes a method for uniquely representing the state of a puzzle or model, enabling the system to rapidly check for solutions or partial solutions.

2. Tangram Implementation

My first prototype, which is being displayed as part of sigKIDS, demonstrates these ideas with the Tangram puzzle. The Tangram, an old Chinese geometry puzzle, consists of five triangles, one square, and one parallelogram, all precisely cut from a large square (fig. 1). One may choose to reconstruct literally hundreds of different shapes with the Tangram pieces.

The Tangram appears frequently in both elementary school math lessons and standardized tests. Very young children use it to gain familiarity with shapes, and learn how to put them together to create new shapes. Older children use it to develop a basic understanding of what "area" and "congruence" are without having to resort to formulas. Overall, the Tangram helps children to develop a geometric intuition that should help them to better grasp more complex geometric concepts later in their school careers.

3. TICLE Setup

My TICLE prototype consists of several pieces. Children play with the wooden puzzle on a 2'x2' Plexiglas tabletop, which they can easily gather around. A videocam, mounted below the playing surface, "watches" the puzzle pieces in play. A bank of lights around the videocam illuminates the puzzle pieces from below. Nearby, a computer monitor shows what the computer "sees". The display also provides two large buttons which may be accessed via a touch screen. The first button plays a short animation describing the object, and the rules, of the game. The second button is used to ask for a hint. A tent-like structure over the entire setup reduces interference from other light sources.

3.1. Tracking Puzzle Pieces

I have marked the puzzle pieces with patterns of reflective colored spots, similar to the approach taken by Underkoffler and Ishii [1998]. These patterns uniquely identify the pieces, while also indicating their locations and orientations. By viewing the pieces from below, I've virtually eliminated the problem of obscuration.

Approximately once every second, the system takes a snapshot of the puzzle's current state. After determining the position and orientation of each piece, the software finds pairs of pieces that are touching one another. Using a shorthand notation that I developed expressing how two puzzle pieces meet, the software generates a substring for each touching pair of pieces [Scarlatos 2002]. This notation has the advantage of being translation and rotation invariant, so that children working with the puzzle need not be concerned about the position or orientation of the finished puzzle. The sub-strings are sorted and concatenated in a string to produce a unique representation of the state of the puzzle. This state string may be compared to a similar string representing the solution, to check the children's progress. This state string is also examined when the children ask for a hint, to help determine what hint should be given.

3.2. The Interface

When children first approach the TICLE system, they are offered a menu of shapes that they can try to recreate with the Tangram pieces. They make a selection by touching the screen. This selection determines what solution is being sought and what hints are to be provided along the way. A brief animation explains what the children are expected to do.

As the children play with the puzzle, the system continuously compares the solution and current state strings. If these strings match, then the children have found the solution and congratulations are offered. If there is a partial match (found by searching for the sub-strings), then the children are making progress. Periodic encouragement is offered as more matching sub-strings are found. Finally, when the children ask for a hint (by touching the screen), the software looks for the presence (or absence) of specific sub-strings in the current state. This, along with a record of what hints have already been shown, helps to determine which hint should be given at that time.

The hints themselves are prepared as short interactive animations. A female voice (supplemented with text) asks a question about a related (but simpler) problem, while the graphics show the pieces in question. The animation then pauses, giving the children time to work out a solution. They may then touch the screen to see what the solution to the sub-problem is. Figure 2 shows a snapshot from one of the hints.

4. Results

We have observed numerous groups of children playing with this prototype at the Goudreau Museum of Mathematics in Art and Science, located on Long Island, NY (fig. 3). For testing purposes, we divided large groups into pairs of children (groups of two), and assigned each pair two tasks. The first task was to make a square out of the Tangram pieces; the second task was to make another simple geometric shape (either a house or a rectangle) out of the same pieces. For the first task, half of the groups used TICLE; the control groups used a conventional Tangram with no outside help. All groups did the second task with a conventional Tangram and no help. We videotaped the children's activities and evaluated them later using Artzt and Armour-Thomas' cognitive-metacognitive framework [1992].

Not surprisingly, we found that most groups using TICLE were able to solve the first problem, while most groups using the conventional Tangram could not. Furthermore, most of the groups that solved the first problem were also able to solve the second. We also found that, in general, children using TICLE spent less time fooling around, and more time discussing approaches to the problem (with discussions frequently triggered by the hints).

5. Continuing Work

I am currently working with two graduate students to develop a version of TICLE that works with a 3D puzzle. I am also working on a system that will enable teachers to define their own puzzles with hints.

6. Acknowledgements

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7. References

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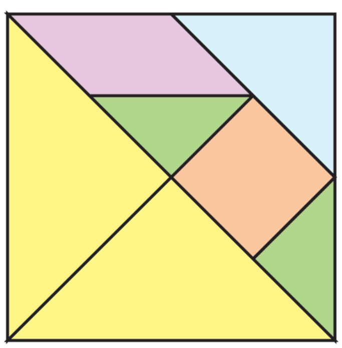

Figure 1. The Tangram, an old Chinese puzzle, can be used to make hundreds of shapes.

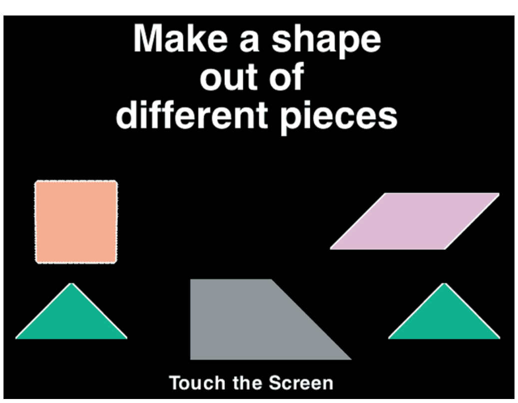

Figure 2. Screen shot of a hint given by TICLE.

Figure 3. TICLE at the Goudreau Museum of Mathematics in Art and Science.