Embodied Fabrication: Body-Centric Tangibles for Digital Making

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ABSTRACT

With the rise of the 'maker movement' and accessible digital fabrication, 3D printing in particular is being rapidly integrated into classrooms, after school clubs, and hacker-spaces. As children are being exposed to 3D printing earlier and earlier, it behooves us as researchers and educators to critically examine ways to effectively engage children in using these devices. This poster reflects on the history of tangible interfaces and cognitive science to frame a promising avenue of research around 'embodied fabrication' devices that offer a body-centric approach to 3D printing and digital fabrication in general. Embodied fabrication takes the core tenets of embodied cognition and their manifestation in recently successful tangibles-based kits for learning to argue for the development of tangible input devices designed for digital fabrication. We take a look at current methods of engaging children in 3D printing, compare them to several recent developments in tangible and embodied interfaces, a take a critical look at potential new directions for research in digital fabrication with children.

FROEBEL TO PAPERT

Many of the influences apparent in the 'maker' movement of today and subsequently on the current research around embodied fabrication devices, have their genesis centuries ago. Friedrich Froebel, the creator of the first kindergarten in 1837, included a set of wooden 'gifts' meant to foster connections between "universal aspects of the external world, suited to a child's development". Froebel's works inspired those interested in childhood education including Maria Montessori, who refined ideas about exposing children to 'manipulatives' The influence of Froebel and Montessori (amongst others) set the stage for Jean Piaget's work with childhood development. While Piaget's theories have been challenged, one of Piaget's intellectual descendants, Seymour Papert, has been hugely influential in connecting theories of children's learning with tangible, computational devices. The creation of the Logo turtle, and the theories of learning presented in Mindstorms opened the door and gave researchers a framework in constructivism with which to transform the intentions of Froebel and Montessori into computationally-enriched manipulatives.

EMBODIED DEVICES

There have been several recent attempts at designing interfaces to enable novice 3D modeling and 3D-printing through tangible interfaces. In KidCAD and deForm, an IR camera system pointed at a deformable surface can read the deformations and stitch together a coherent 3D model. This ability of stamping pre-made objects allows young children to generate complex designs by combining several pre-made objects together and to add details by hand, pencil, or brush. As of writing, the ability to natively 3D print the created shapes in still a work in progress. VizTouch automatically generates a 3D-printable file of a variety of mathematical formulae by extracting relevant information from an excel file. Printing mathematics concepts (e.g. a graph of a polynomial function) may foster greater understanding among many kinds of students.

The Easy Make Oven is an interactive tabletop that allows users to scan real objects, perform simple gestural manipulations on a scanned model, and export the altered shape to a 3D printer. By allowing the scanning of real-world objects and gestural modeling actions as opposed to creating a digital model from scratch using sophisticated CAD tools, the Easy Make Oven lowers the barrier to entry for creative and embodied 3D modeling in an accessible, child-friendly way. The UCube is a tangible user interface that facilitates the modeling of basic classes of shapes on a grid-like platform. Users place vertical towers in certain (x,y) positions on the board and then flip switches to specify a particular coordinate in 3D. The tangible board connects to a piece of software that displays the active points in real-time against a 'ghosted' grid of all the potential points in the grid (e.g. a 4x4x4 grid has a potential 64 points). The software can then interpret these points in different ways, for example by taking the convex hull of the active set. These models can also be directly exported into a 3D printable file format. Easigami is a tangible user interface that, like Posey, allows users to connect a set of shapes and have software recognize the morphology of the model. The paradigm of origami folding is incorporated into the shapes via the hinge-like mechanisms that serve to attach two pieces together and allow the two faces to be posed at different angles to each other so that, for instance, one could use eight equilateral triangles to form an octahedron. Going through the process of manipulating physical triangles (vs.digital ones) we may argue that the user gains a deeper understanding of certain geometric concepts. A real-time screen representation is shown on a computer, potentially allowing users to gain insight into how 3D shapes are typically represented on a 2D screen. Easigami also allows the option of saving a model to a 3D printable format.

With the rise of digital fabrication and especially 3D printing, researchers and educators ought to take a more embodied approach when designing fabrication tools for kids. Traditional child friendly software-only solutions promote a 'download and print' mentality that robs children of exploring the deeper concepts embedded in 3D printing. Given the potential of this relatively unexplored field, it is our hope that more practitioners begin to think of digital fabrication with children as being an opportunity to employ tenets of embodied design as a means of deeper discovery and engagement.

PROGRAMMABLE BRICKS

Papert et al.

MANIPULATIVES

Montessori

FROEBEL'S GIFTS

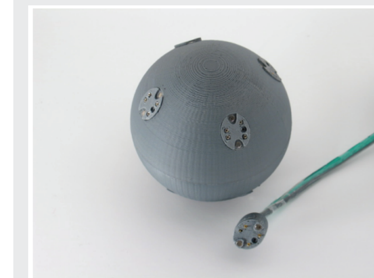
Pictures courtesy of Froebel Gifts USA

Froebel

ROBLOCKS

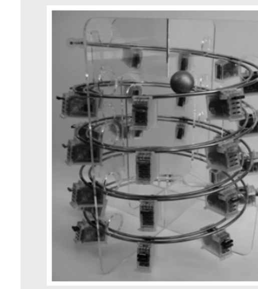
Schweikardt and Gross

GRAPHMASTER



Schweikardt, Elumeze et al.

MARBLE TRACKS

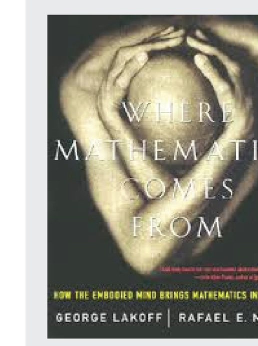


Fischer and Lau

HEARING GESTURE

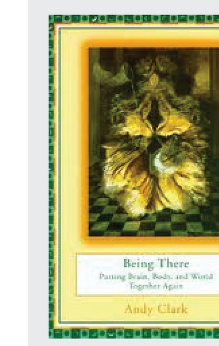
Susan Goldin-Meadow

WHERE MATHEMATICS COMES FROM



Lakoff and Nunez

BEING THERE



Clark

TANGIBLE USER INTERFACES
A device that uses smart computational elements in a form that helps solidify concepts to a user

EDUCATIONAL TANGIBLES
The use of physical objects designed for children's education, e.g. building blocks, LEGO, etc.

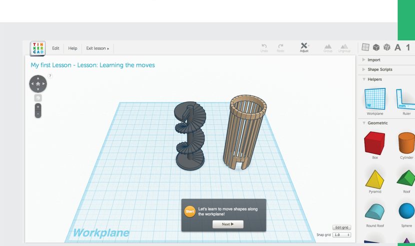
EMBODIED COGNITION
The belief that our cognitive processes are deeply rooted in our physical, bodily interactions with the world.

DIGITAL FABRICATION
Various means of creating or modifying physical objects based on a digital design file

EMBODIED FABRICATION
The application of embodied design principles in the creation of TUIs for digital fabrication

EMBODIED DESIGN
The design of body centric human computer interactions influenced by embodied cognition

TINKERCAD



Screen-based software for 3D

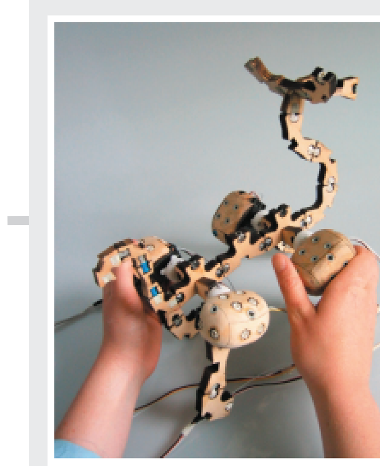
CUBE

Desktop 3D Printer

LASERSAUR

Open-Source Laser Cutter

TOPOBO

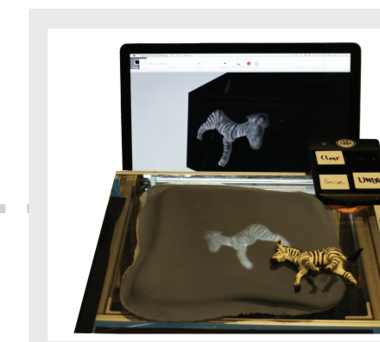


Raffle et al.

POSEY

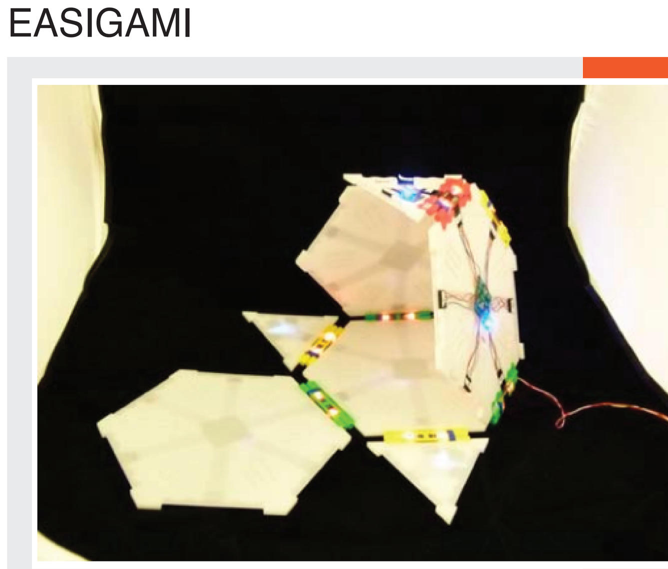
Weller et al.

KIDCAD



Follmer and Ishii

EASIGAMI

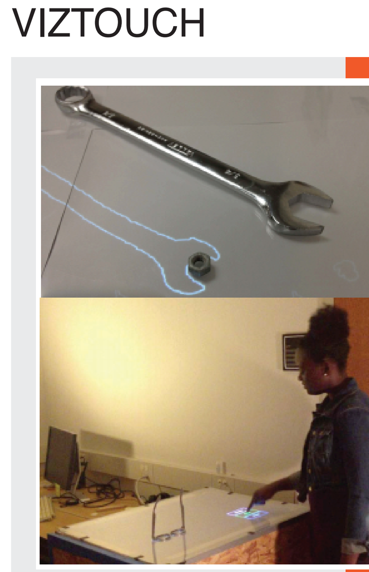


Huang and Eisenberg

UCUBE

Leduc-Mills and Eisenberg

VIZTOUCH



Brown and Hurst

CONSTRUCTABLE

Mueller et al.

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