Popup WorkShop: Computationally Enhanced Paper Engineering for Children

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Ph.D. Dissertation Defense

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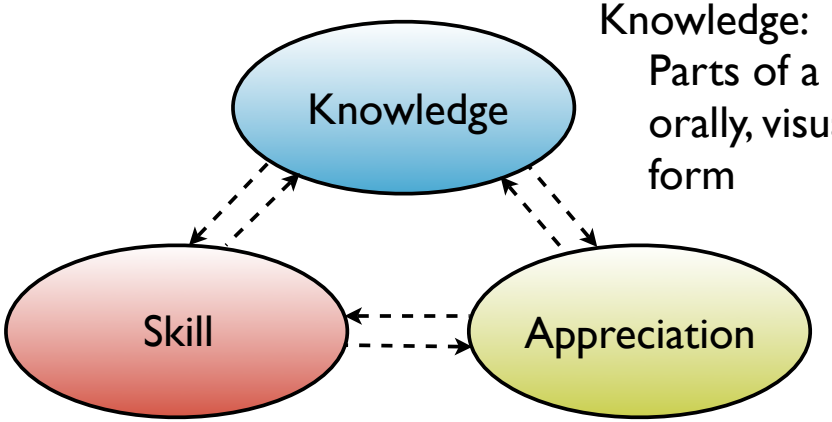
Overview

- What is craft?
- What are pop-ups?
- Why should we care?
- What does Popup Workshop look like?
- Problems and solutions, including related research
- What do children do with it?
- Contributions and future work

What is Craft?

The production of physical objects by manual means



Knowledge:
Parts of a craft transmitted orally, visually, or in written form

Skill:
Actual practice of the craft learned by doing

Appreciation:
Understanding and enjoyment of results, tradition and aesthetics

This framework can be applied to:

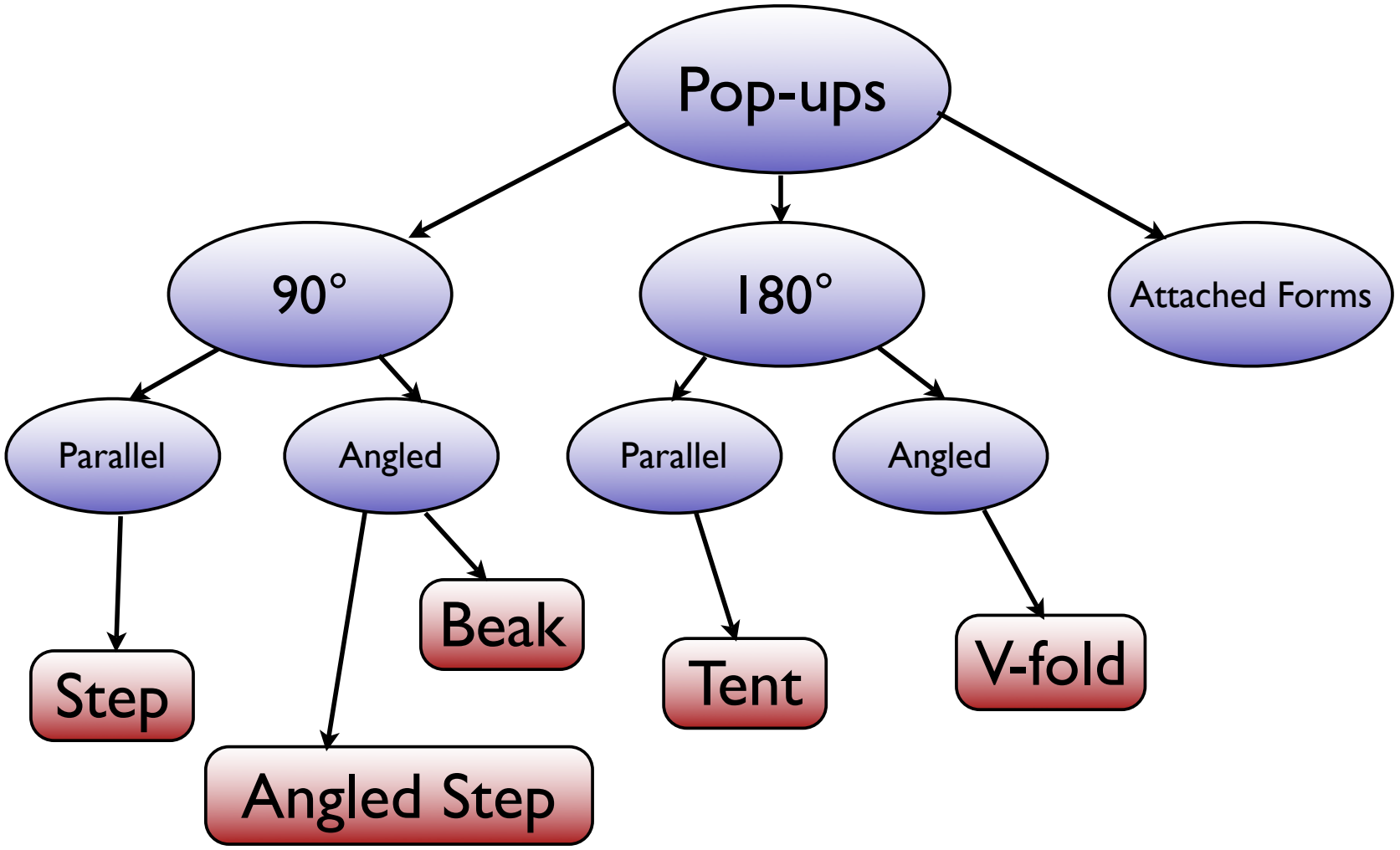
analyze and simplify the design of craft software
organize the usability assessment of craft software

What are pop-ups?

3-Dimensional

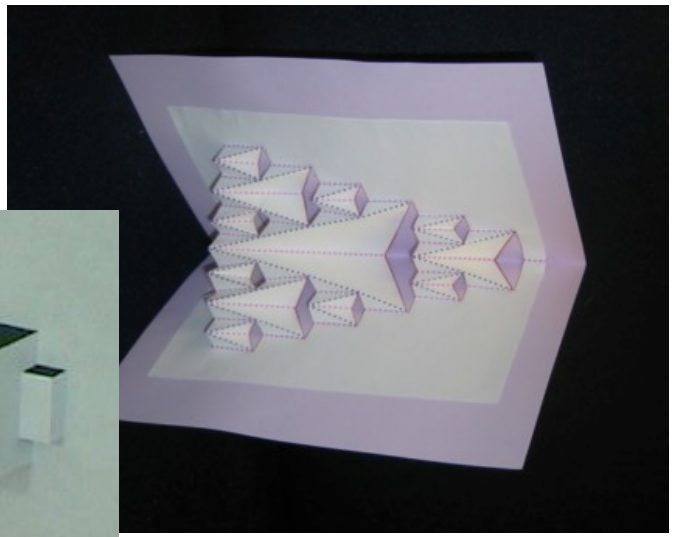
Automatic

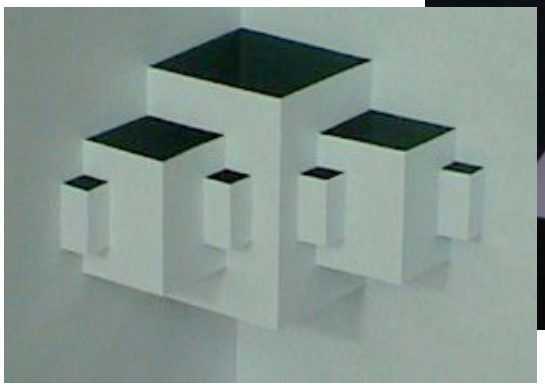
Pop-up Elements



Why Study Pop-ups?

- Part of children's culture and attractive to children
- Combines verbal, mathematical and artistic elements
- Curricular applications
  - Literacy
  - Mathematics





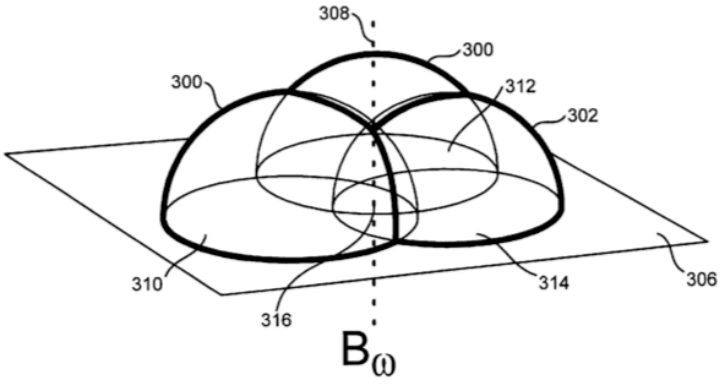
Demonstration of Popup Workshop

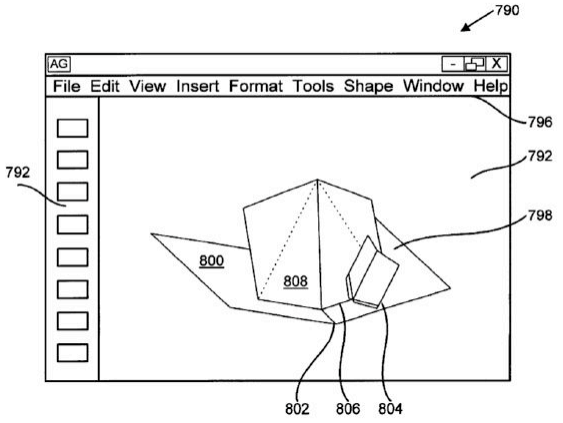
What Does Popup Workshop Do?

- Add and edit a variety of design elements, keeping them foldable
- Print the result, saving in some format to allow sharing between users and export to other software
- Other editing features (color, etc.)
- Showing both the 2D design and the 3D result
- Animation of the pop-up

Previous Research - Andrew Glassner

- Aimed at card making hobbyist
- 3 papers and a patent
- Uses set of equations for 3 intersecting spheres to find each point in animation.
- Has used his program to make his own cards, but it is not available for use



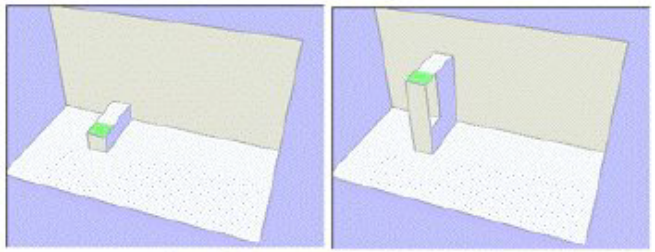


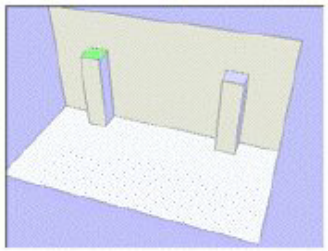
Previous Research - Nanyang Technological University

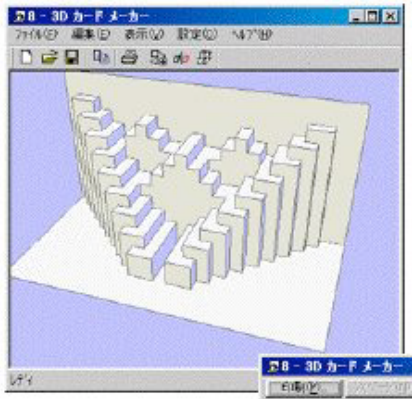
- Aimed at automation of commercial production of pop-ups
- 2 papers on mathematical properties of pop-ups
- Animation method for 180° elements but no interface for editing
- Trigonometric solutions for points on two types of elements
- No software produced

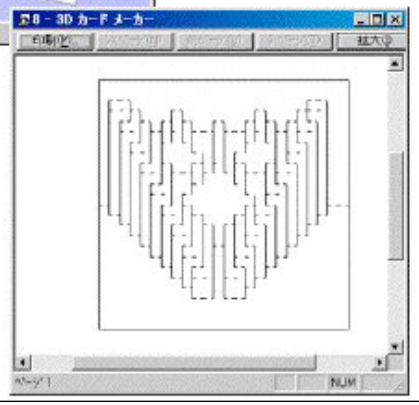
Previous Research - Jun Mitani

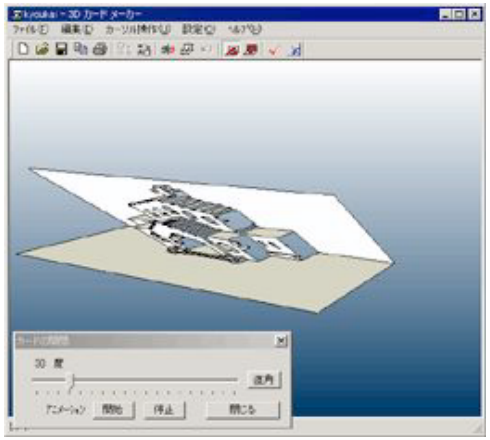
Opening of Θ for (x, y, z) at Θ=90°
the 3D points (X, Y, Z) are:
X = x
Y = y-z(cos Θ)
Z = z(sin Θ)











- Aimed at origamic architecture community
- Actual software--Pop-up Card Designer
- Only steps, so simple to animate

What Are The Most Important Problems?

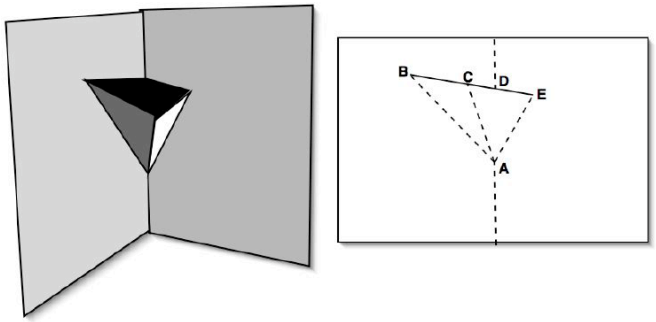
Keep the elements foldable

Elements can be on top of each other

Animation

Keeping Elements Foldable: Geometric Constraints

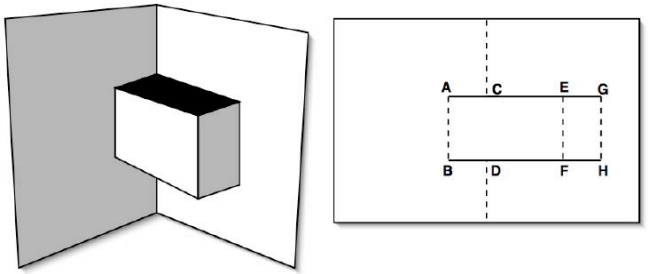
Beak (angled)



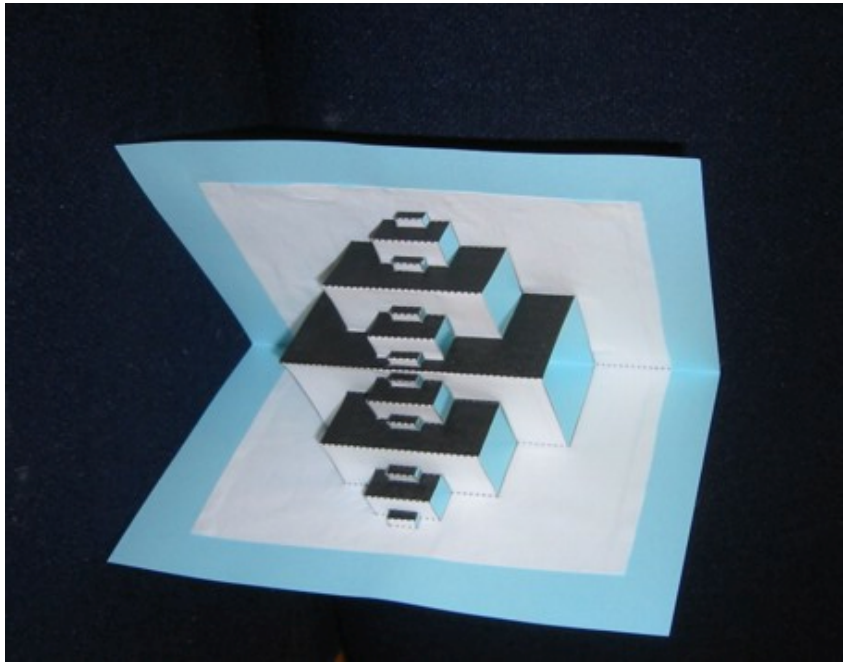
∠BAC = ∠DAE
Point A on the parent fold

Step (parallel)

line AB || line DC || line EF || line GH
distance from AB to CD = distance from EF to GH



Elements on Elements



Changes or movement in a supporting element changes the elements above it

Removing an element requires removing elements on top of it

Planes need to be cut out when a new element is added.

Solutions:

Ordered representation of elements

Way to add new points and remember which are old points

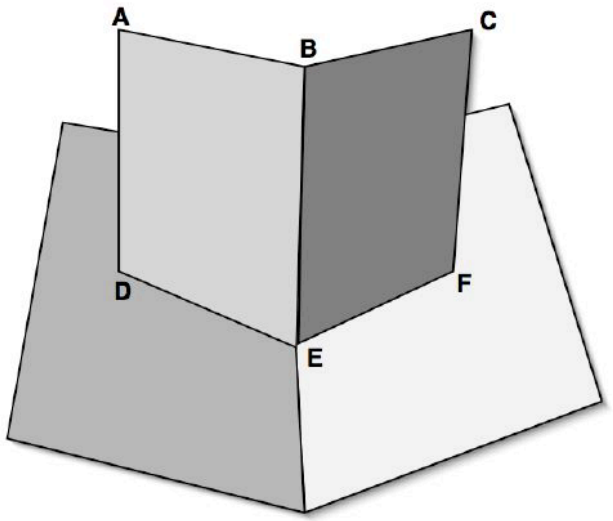
Pop-up Animation

- Focus of most research to date: All use mathematical formulas
- Constraint system solution:
  - Allows addition of new elements without requirement that we know their mathematics.
  - Works for all types of pop-up elements.
  - Possible problems with constraint solutions:
    - No solution is found
    - More than one solution possible
    - Speed

Popup Workshop Animation

Constraint system solution with greedy algorithm

- Take advantage of the fact that some distances remain constant.
- Some points are anchored (attached to the base plane): D, E, and F.
- Some points are unanchored: A, B, C

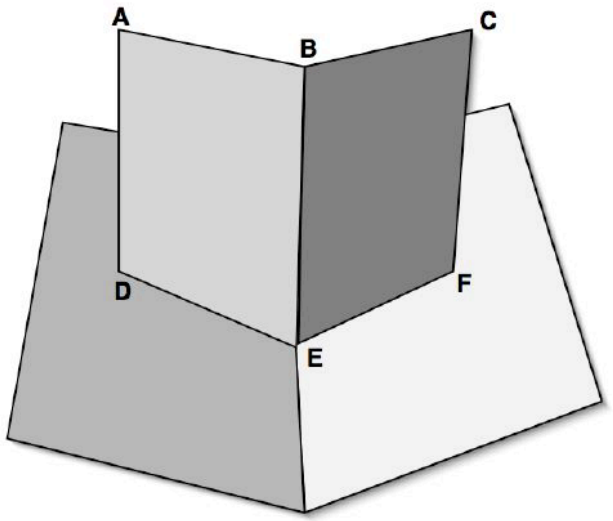


Popup Workshop Animation

Constraint system solution with greedy algorithm

- Find the anchored points first for each element. Find the unanchored points second.

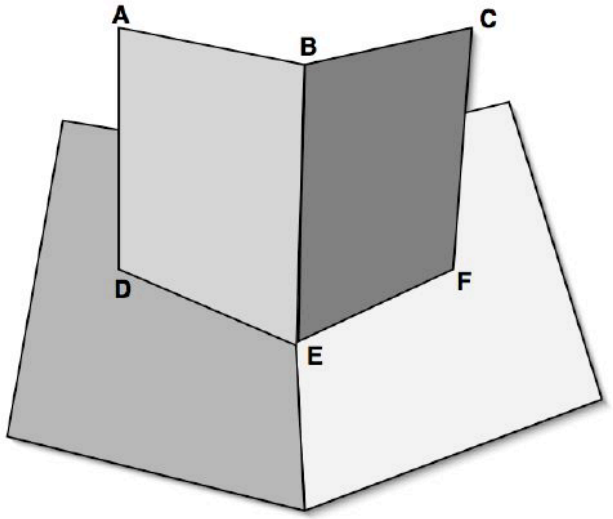
- Find a new point such that the distances from some other points remain the same as they were before the pop-up was changed.



Popup Workshop Animation

Constraint system solution with greedy algorithm

- Choose a trial point location.
- Calculate the distances to the previously found points.
- If they are within tolerance, then stop.
- Otherwise, move the point so that the distance with the worst fit is corrected.
- Try it again.



- If it is not found within a certain number of iterations, stop and use what we have.

Early Testing

- 5th graders, middle school children, and adults
- Missing:
  - Users over a longer period of time with more pop-ups
  - Wider range of ages
  - More element types with a better pop-up making and observation environment

Formal User Testing

Series of individual sessions

Greater age range

Rich environment

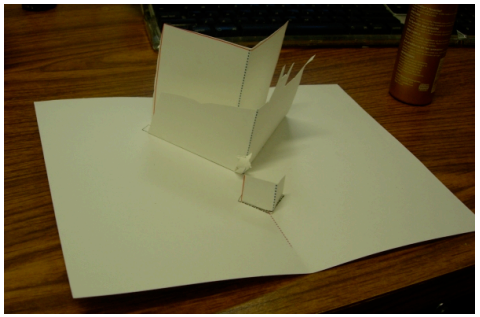
Question sessions

Email followup

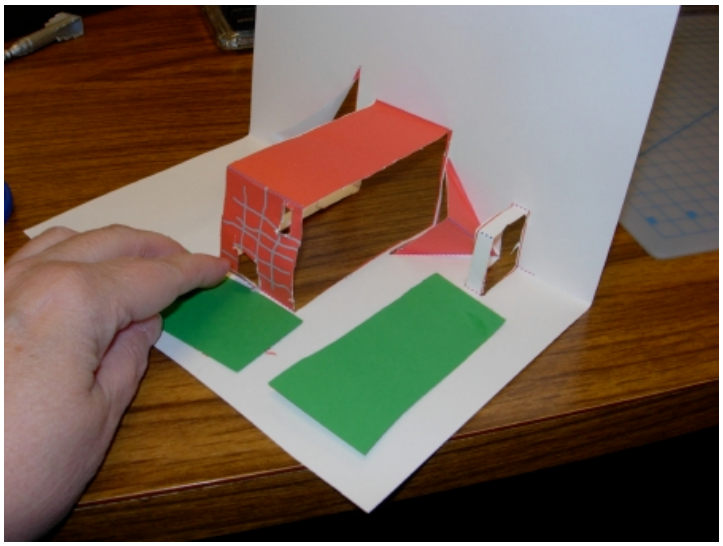
Pre- and post-testing

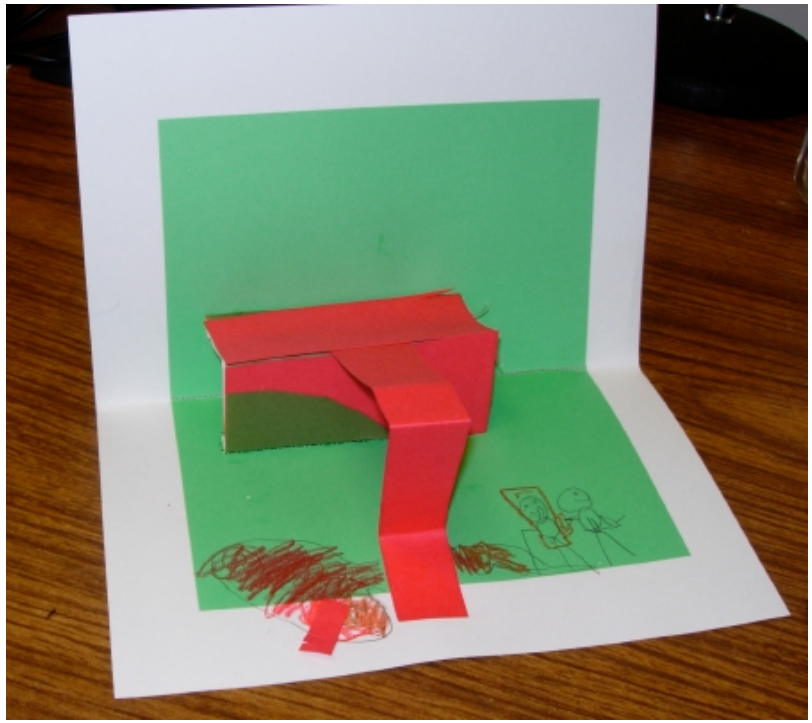
Richard

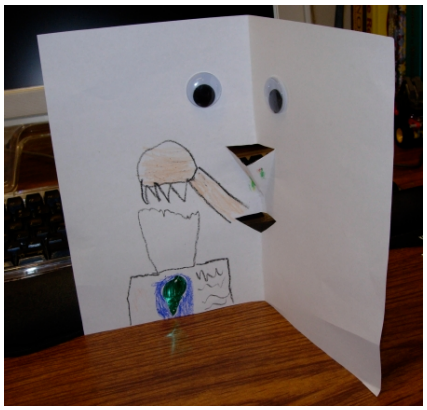
(Pseudonyms are used throughout for users.)



6 years old, 5 sessions, 7 pop-ups

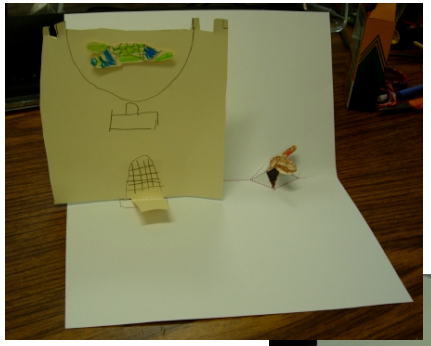


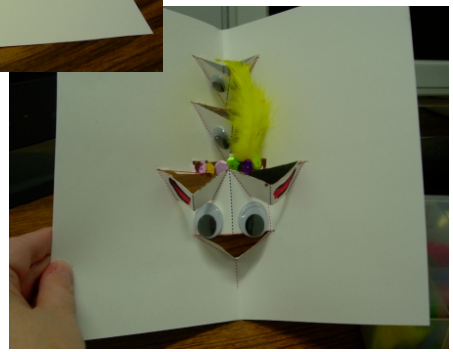


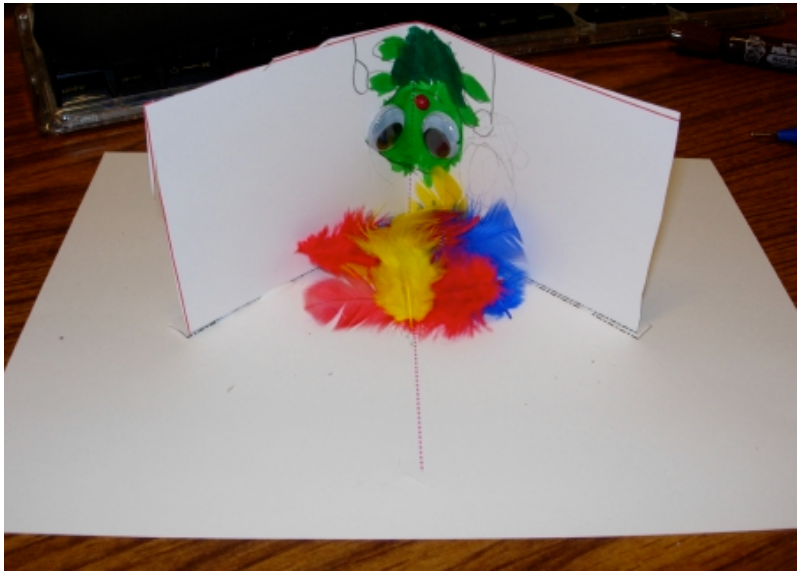


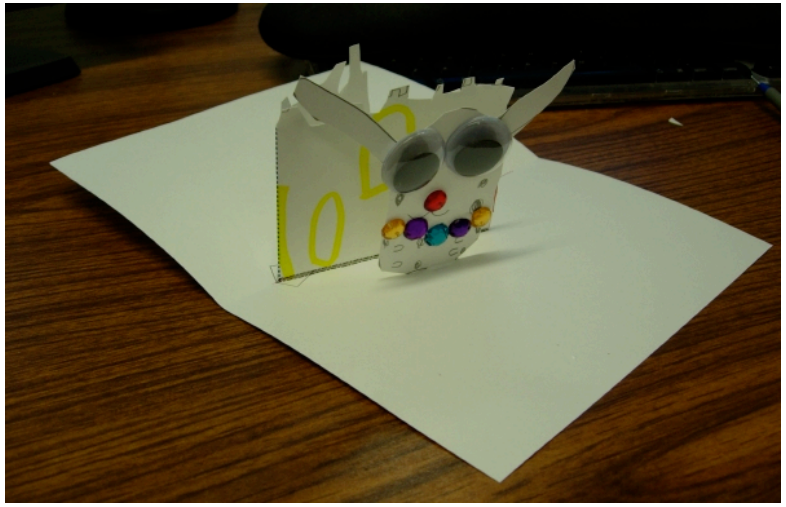
Ursula

6-7 years old, 8 sessions, 14 pop-ups



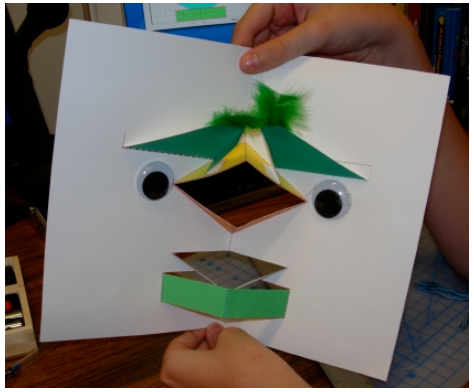






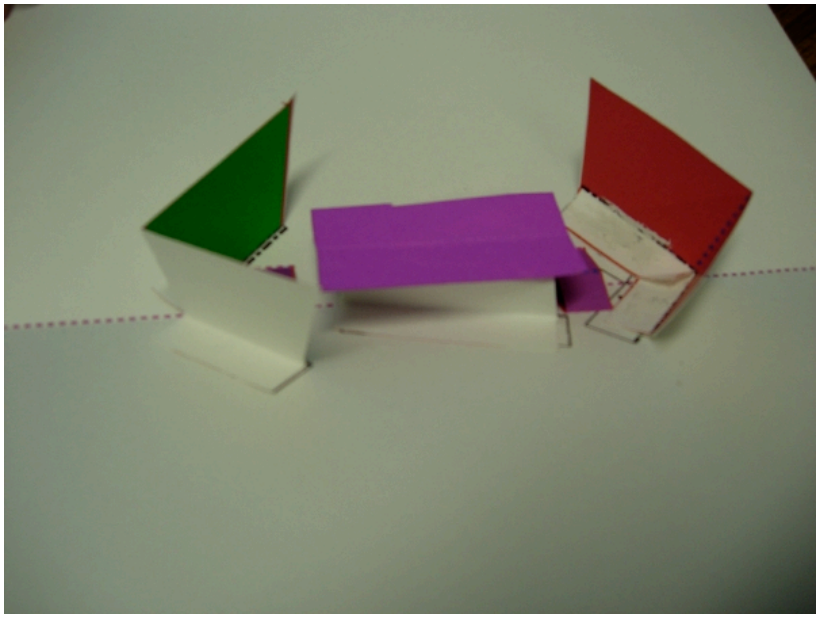
Daisy

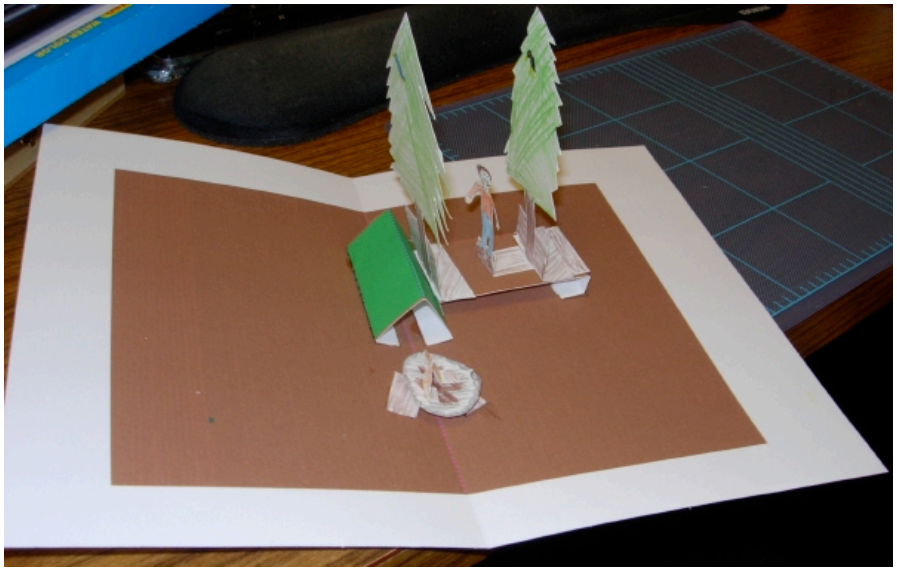
12 years old, 7 sessions, 7 pop-ups



Peggy

11-12 years old, 8 sessions, 4 pop-ups



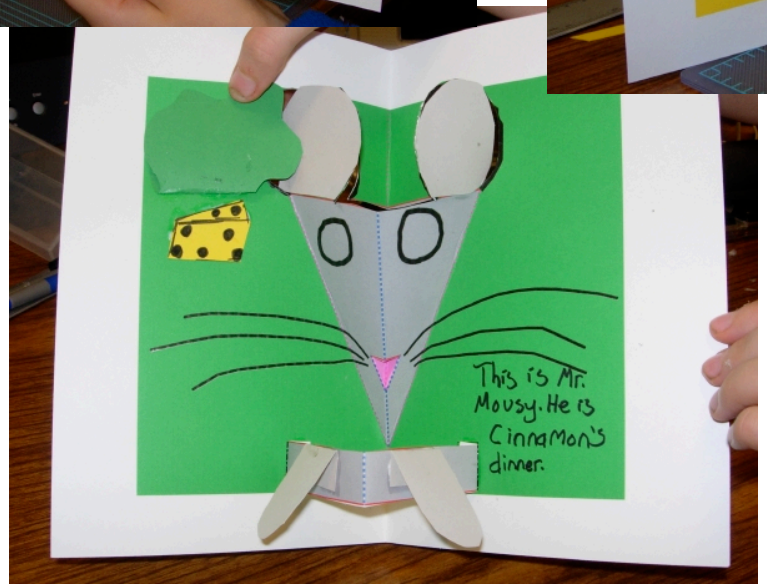


Emily

11-12 years old, 13 sessions, 10 pop-ups

1

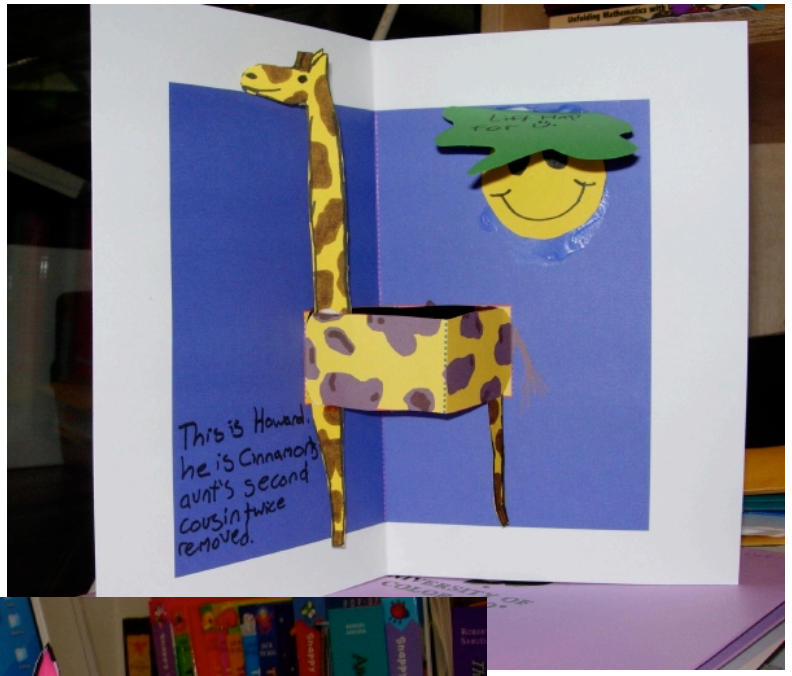
2



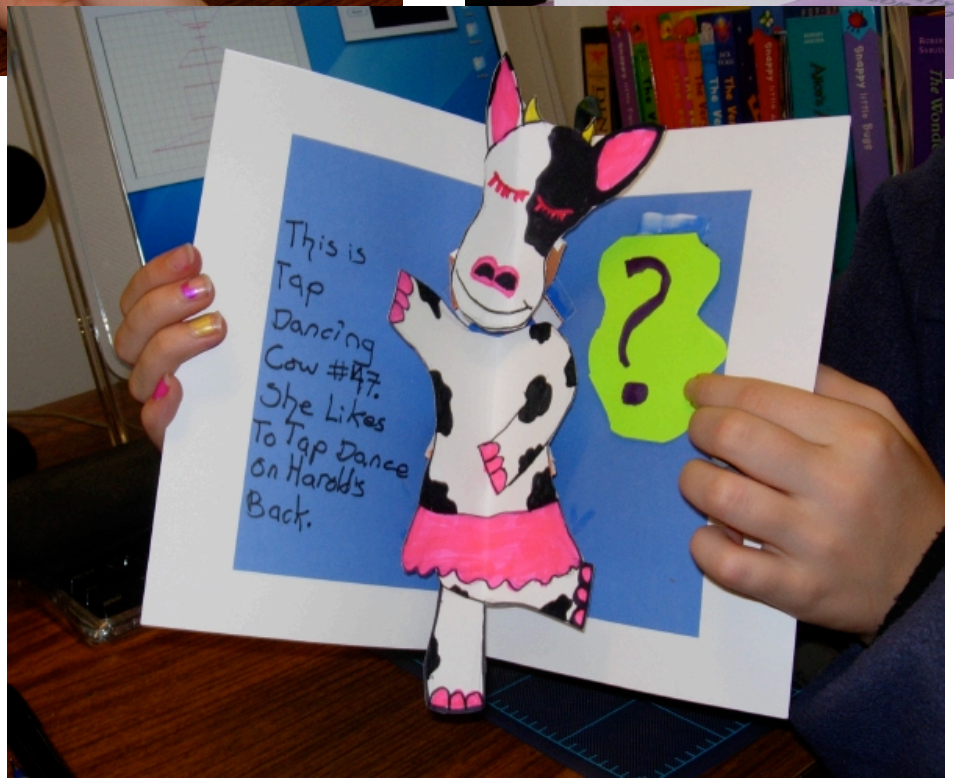
3


This is Mr. Tweedy best friend. Cinnamon ate him last week.
Mo. He is Mr. Mousy's

4


This is Howard. he is Cinnamons aunt's second cousin twice removed.

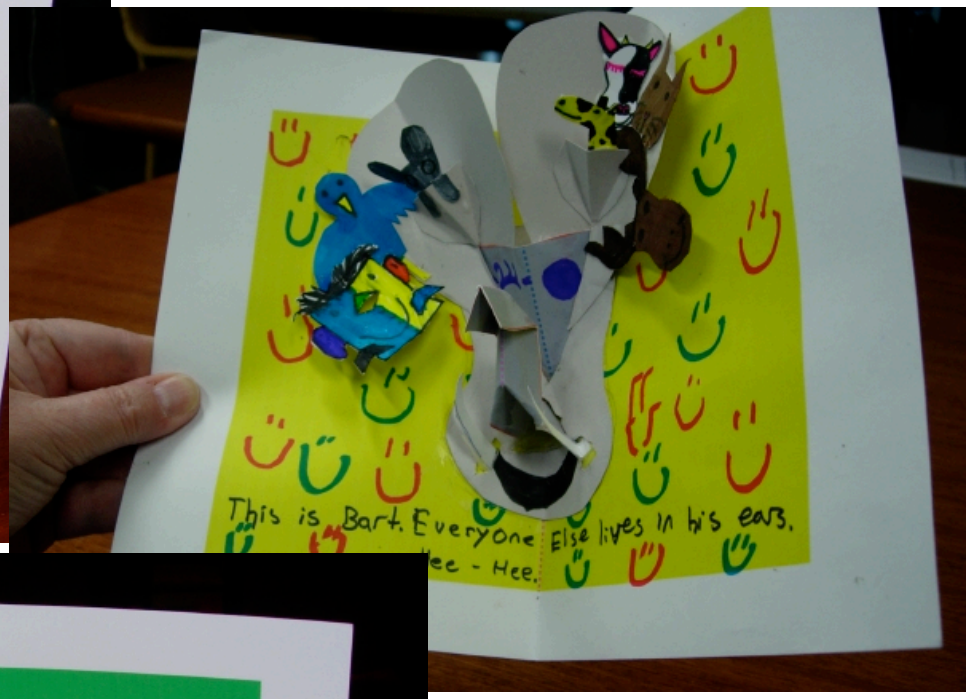
5


This is Tap Dancing Cow #47. She Likes To Tap Dance on Harold's Back.
?

6


Pull
Pull
Ex-Boyfriend.

7


This is Bart. Everyone Else lives in his ears.
Hee - Hee.

8


Slide of Ignoran
Warning! Imminent Doom Ahead!!

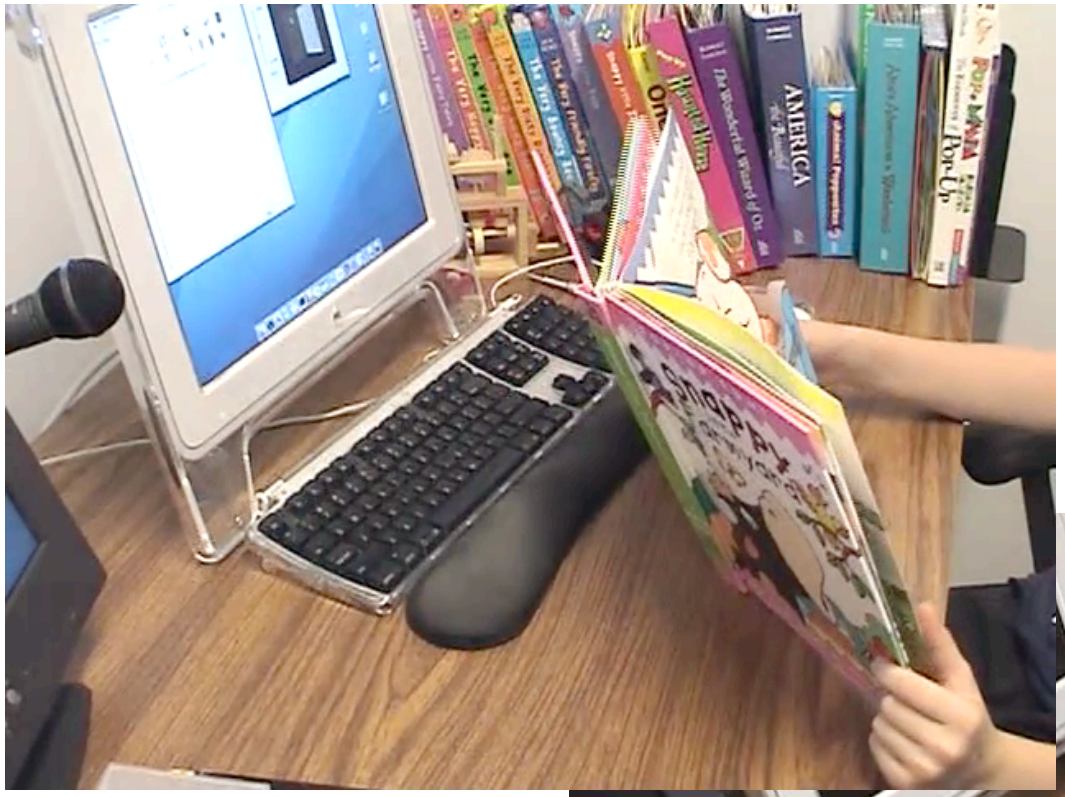
9

Results - Knowledge

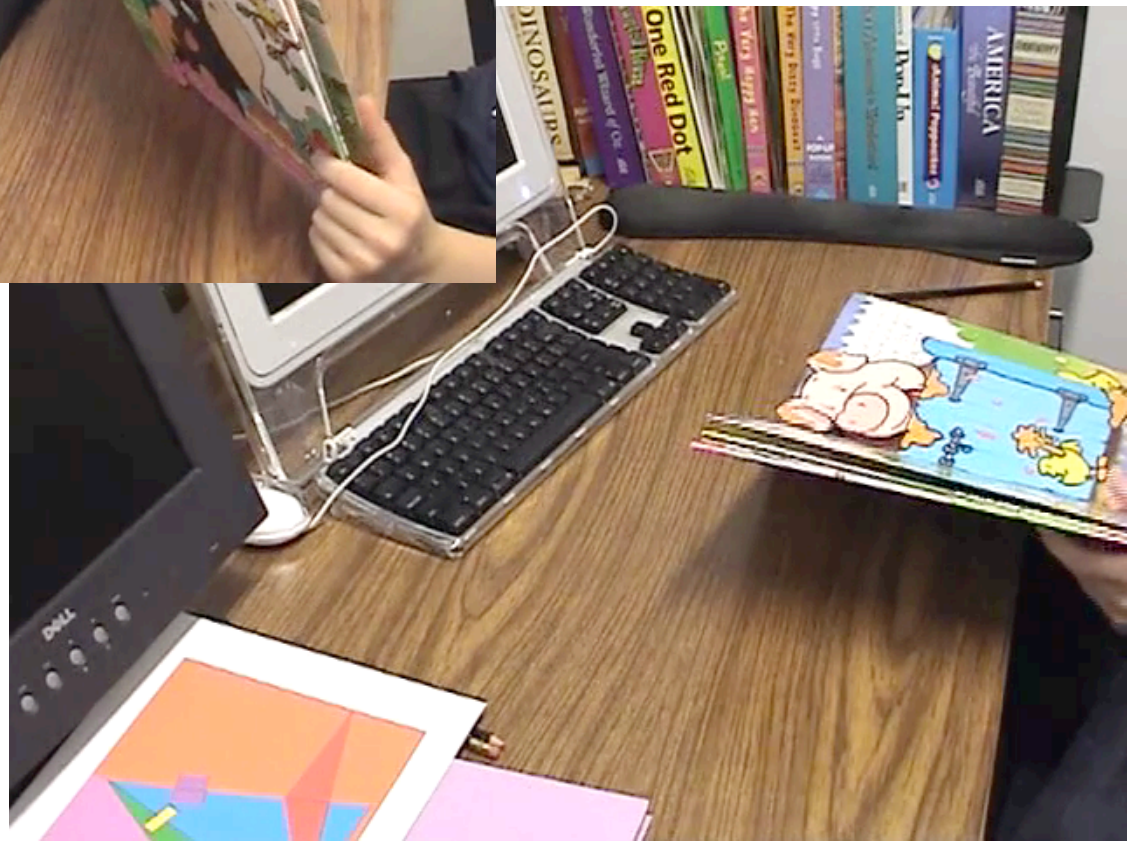
Vocabulary: element names
6 elements total with 5 children
18 of 30 names correct

Most common mistakes:
Confusing "tent" and "step"
Confusing "beak" and "v-fold"

Possible related factors:
Time on task
Age
Pop-ups made

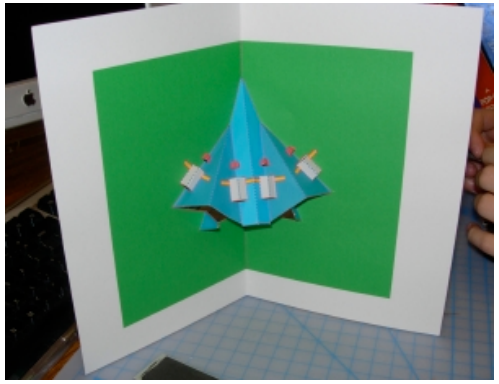


Emily 11/05/06



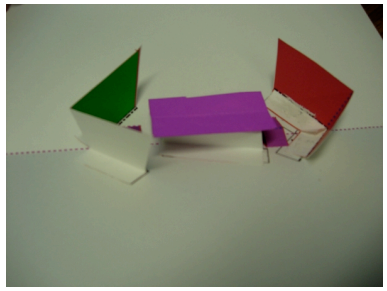
Emily 3/24/07

Results - Skill

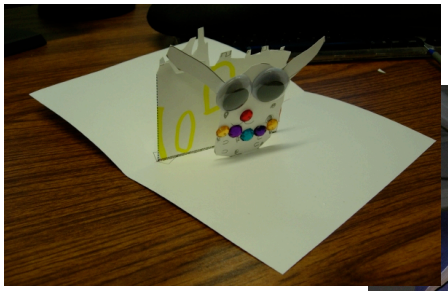


Replication and multiple layers

Non-software elements



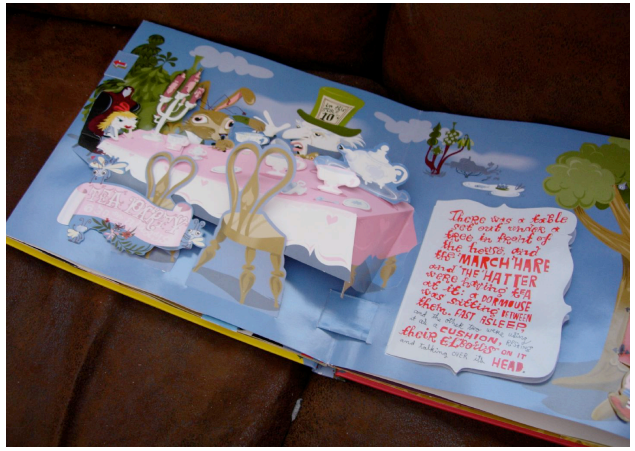
New uses for elements



Attached planes

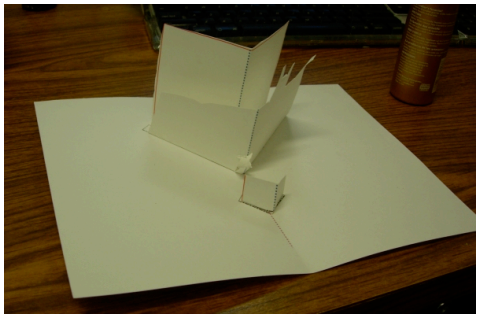
Alteration of elements

Results - Appreciation

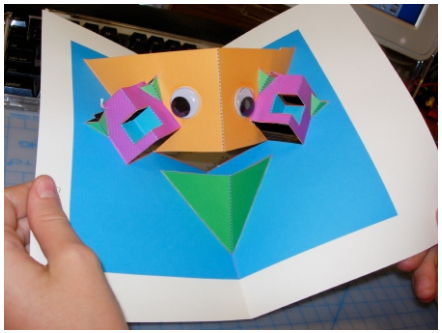


Comparison of pop-ups

Where the ideas came from

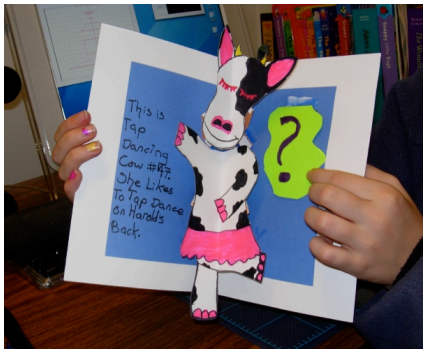


Pop-up books



Software

How-to books



Other kids

Other Observations

Motivation

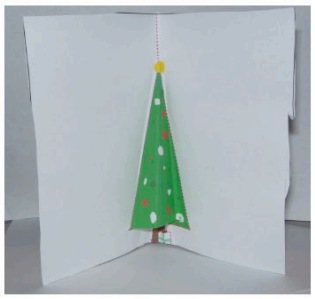
Age range

Multiple working styles and interests

Viewer window

Continuing Work

Social currency

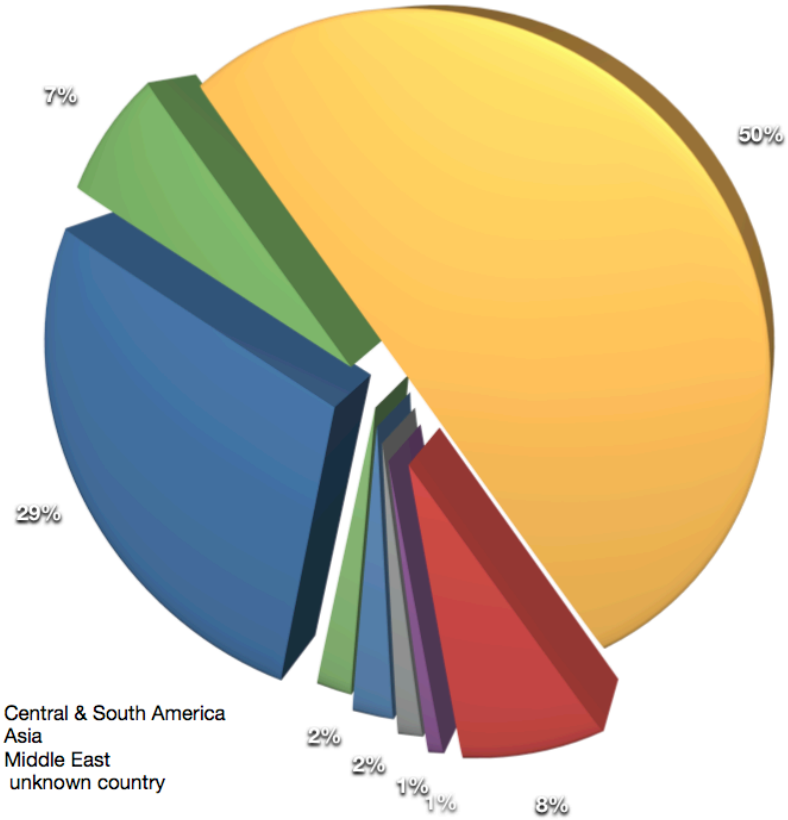


Web Downloads

March 2005 - September 2008:
2942 downloads
1590 unique users leaving information

Versions 1.1 and
2.0 for Mac and
Windows/other

73 Countries



Future Work

- Software Additions and Enhancements
  - Constraint system enhancement for better selection between multiple solutions
  - Development of language description of new elements to make addition of new elements easier
  - Animation speed enhancements
- User Studies and Curricular Applications
  - Study of methods of children's design and artistic development
  - Group work and classroom studies

Core Contributions

- **Popup Workshop**
  - First general purpose program available to public.
  - First such design software for children
  - Proof of the effectiveness of a constraint system for pop-up animation
- **Craft Framework**
  - Allows examination of areas in which computation may be beneficial, and those in which it may not be, and aids in the design of craft software.
  - Used in assessment of the user testing, where craft software is often difficult to assess.
- **Literature Surveys**
  - Computational enhancement of paper engineering.
  - Uses of pop-ups and pop-up making in the classroom.

Acknowledgements

- Advisor: Michael Eisenberg
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