Popup Workshop:
Evaluation Rework

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1 Introduction

This paper is the result of my committee's request for a more thorough and detailed look at the evaluation methods in my thesis research. During my search for the best way to evaluate this software, I have found the need to produce a document to explore this question; I feel that to put out a revised proposal document is not the best course to take. There has been additional work since the proposal that should be presented; it seems to me to make more sense to produce a new document and let the original proposal stand for at least historical interest.

In addition, I found it helpful to put down all my thoughts in this matter in one place to help compose my thoughts.

Readers who wish to cut right to the chase may start with Section 4 which describes in detail my proposed evaluation for the thesis.

I am including a summary of work which has been done since the proposal (Section 2), to insure that all the readers are acquainted with the current state of my research. In addition, I lay out an overview of possible research related to pop-ups and this software (Section 3) as a prioritized list to serve as a guide. I then establish the thesis work as the top priority which I expand in Section 4.

I have included my original thesis question (Appendix A), the original research contributions (Appendix B), and the original evaluation description (Appendix C) in this document for ease of reference. The full proposal is available separately [5].

I hope that this document will serve as a discussion point for going forward with this work, and perhaps as a plan that meets with your approval.

2 Activities since the proposal

This section is a summary of progress, both with children and on the software, that has occurred since the proposal. Readers may want this information in order to get a complete idea of where I am, as background to where I want to go.

This section discusses software changes, user testing with both children and adults and other activities. I close with a section listing the lessons I've learned from these activities.

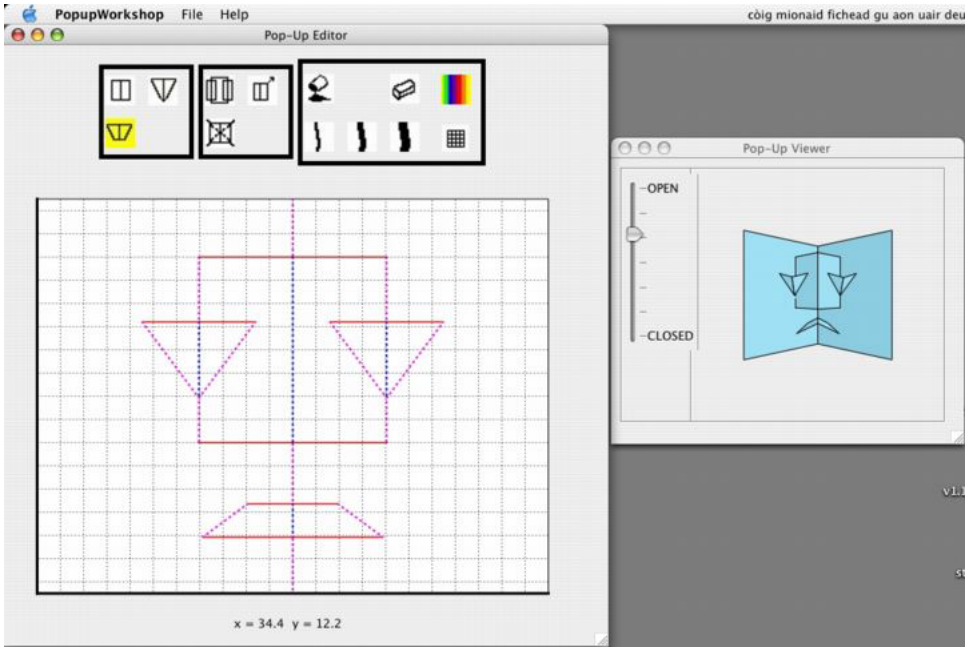

Figure 1: Popup Workshop V1.1 screen

2.1 The software

Since the prototype software discussed in my proposal, two versions of the program have been built. Version 1.0 added a working print capability and removed the ”add text” decoration button–which was not supported at the time–in order to avoid confusing users.

Version 1.1 (which is the current version) saw several changes in functionality. First, more items in the ”File” menu were added. The user can now export a copy of the editor page as a jpeg in order to decorate it in other programs. There is also a ”Save” option, which saves the current state of the pop-up as an XML file. This is accompanied by ”Save As”, ”New”, ”Revert to last saved” and ”Open” menu items. In version 1.1, I also added a display of the Cartesian coordinate position of the mouse when the mouse is in the viewer window. Versions now exist for both Macintosh and Windows computers. A screen capture of this version is shown in Figure 1.

A less visible change (for the user) is in the constraint solving algorithm for animation. A greedy algorithm replaced the original hill-climbing. This is faster, although no more accurate.

As of this time, version 1.1 of Popup Workshop has been on the CTG website ([4]) for about a year; version 1.1 has been available for download since about February of 2005. Recording of downloads was started at that time. As of June 28, 2005, 82 downloads have occurred. In 57 of those downloads, at least some of the requested information was filled in. These download requests came from 15 US states and 17 countries. (Unfortunately, I’ve gotten little feedback from these users. Only two people have actually discussed it with me.)

Version 2.0 of Popup Workshop has been started. A sample applied structure (one requiring a separate piece to be added to the base page) called a v-fold has been added. The largest amount of effort in adding v-folds was in three items: adding the extra pages themselves, which involved GUI changes, the modification of data structures to accommodate and reference multiple pages and their interactions, and coding the constraints for the v-fold. These constraints control where the points can move when the user changes the structure, and are separate from the constraints used for animation. The animation of the new structure required very little effort.

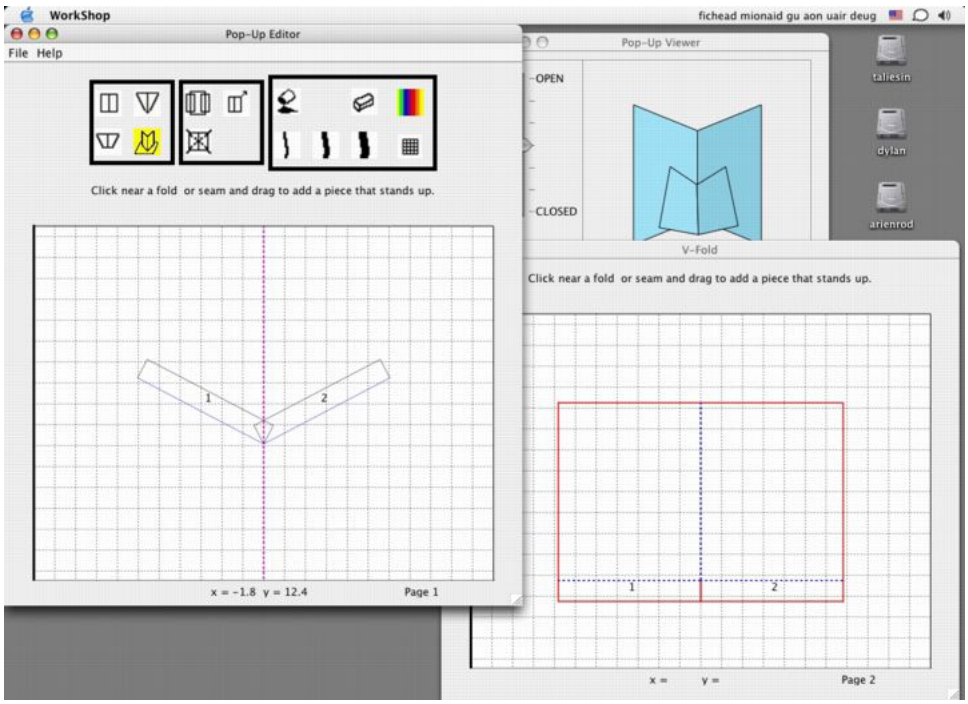

Figure 2: Popup Workshop V2.0 screen, as it currently exists

A screen capture, demonstrating the addition of a v-fold, is shown in Figure 2. Notice that numbered tabs and bases are included with the addition. The addition of multiple pages was a major change. Bug fixes and complete regression testing are in progress.

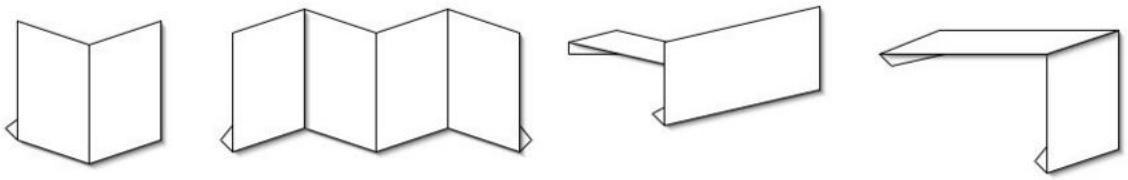

Figure 3: From left to right: v-fold, m-fold, attached plane, and parallelogram

Other changes are going into Version 2.0, which will be the version used for the thesis evaluation. I want to add three additional types of applied elements: m-folds, attached planes, and parallelograms (Figure 3). The time involved in adding these, once the v-fold addition is complete, should be minimal.

M-folds are much like v-folds, but they have an additional plane at each end. Their change constraints are similar to those of v-folds, for which the work is already done, and adding them should present no difficulties. Second, are add attached planes. These are simple single planes which are attached to existing elements by a strut. Their properties and constraints are simple. Finally parallelograms, which are very similar to the parallel double slits that exist in version 1.1, but without a cut on the base page. Instead, they are applied to the base page. Once again, the constraints for changing these are well understood. In addition to v-folds, these three applied structures will allow a great diversity of possible designs, and are some of the most commonly used

elements in professional pop-ups.

The addition of applied elements requires that changes be made to the Viewer window, as they introduce more complex interactions.

Therefore, the Viewer window will become a Java 3D window, and I will need to store the "cut-away" versions of planes (with the cuts taken out of them). This should also allow twirling of the animation for better viewing. My experiences with users over the past year have convinced me that it is important to provide a good Viewer for user testing.

2.2 Activities with users

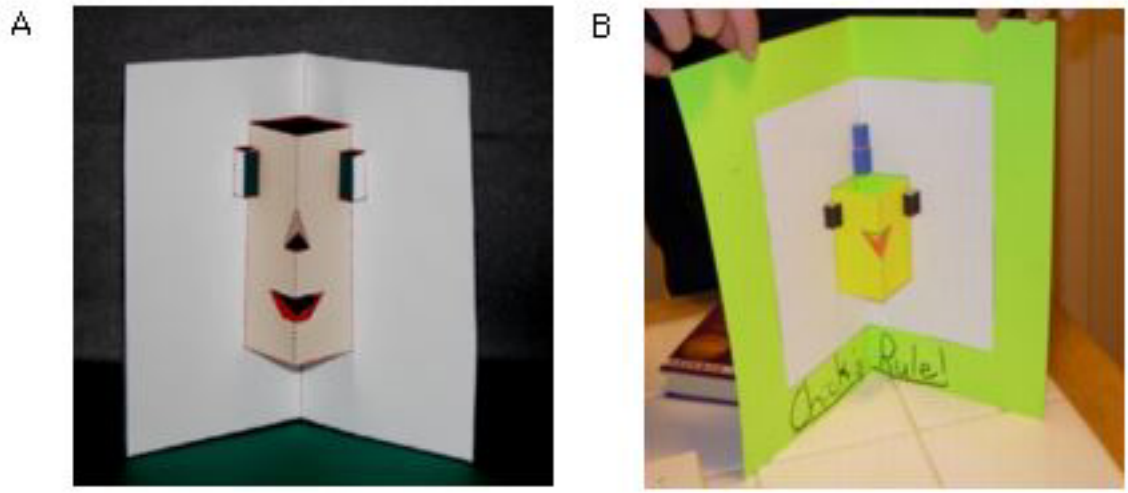

Figure 4: Pop-ups made by 5th grade students

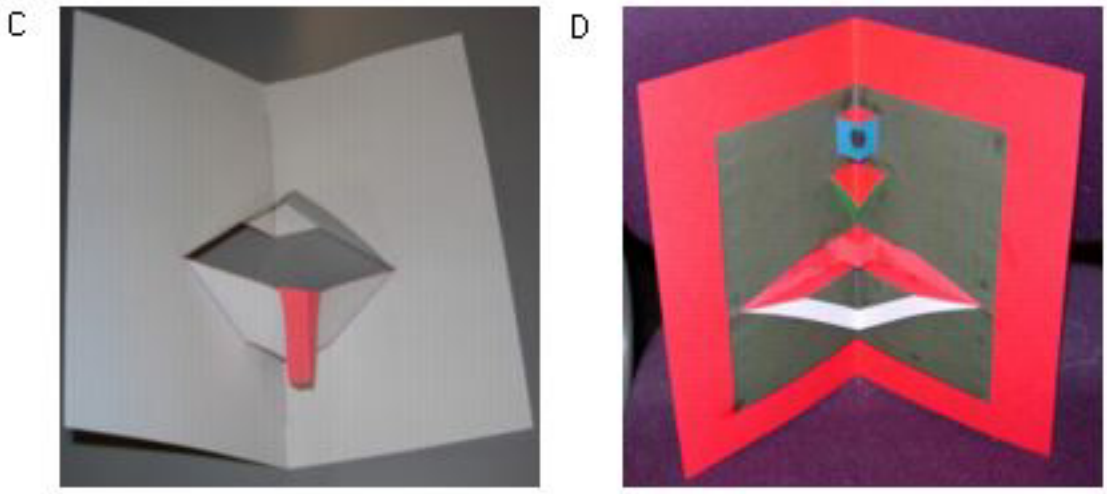

Figure 5: Pop-ups made by 5th grade students

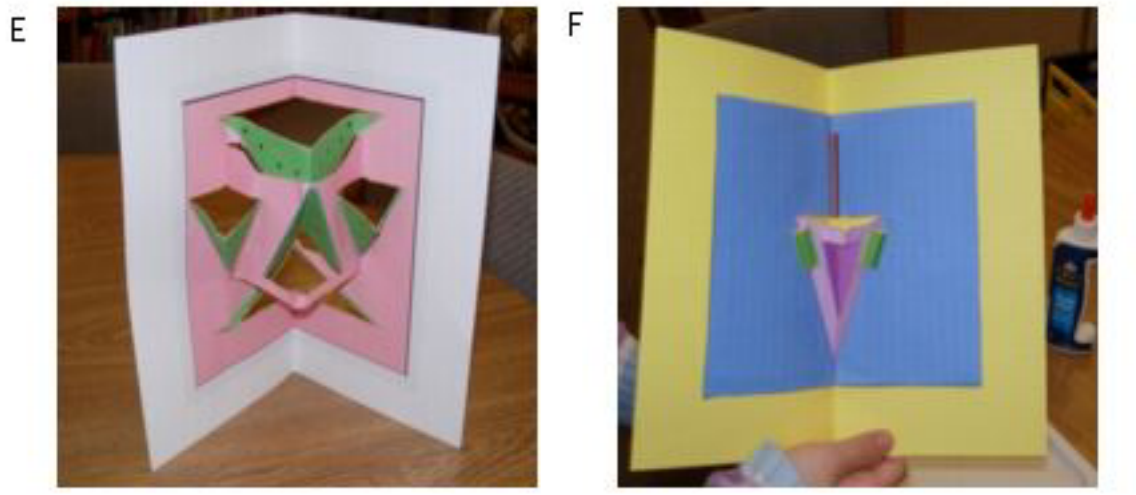

Figure 6: Pop-ups made by 5th grade students

At the time of the proposal defense, only one child had worked with the software (and produced one pop-up, see Figure 4 Photo A). While results were promising in this trial–the child appeared to enjoy the experience, was pleased with the result, and produced the pop-up easily–this was not enough data for me to come to any conclusions about student's use of the tool.

Since that time, I have worked with more users, and have initial results from that work. This section describes those experiences, and shows some photos of the pop-ups that were created.

2.2.1 5th grade users

Figure 4 shows the pop-ups from my first two trials with 5th grade students. Both of these were informal building sessions in which I provided help as needed. Photo A was done by a student from Whittier Elementary School in Boulder in the spring of 2004, and photo B by a 5th grade student from Brush Creek Elementary School in Eagle, Colorado, in the summer of the same year. No media recording of any kind was done in these trials, and I kept only an image file of the pop-ups which could be used to reproduce them, and photos of the pop-ups themselves. Working with the software and building the pop-up took less than an hour in each case. In B, the child added written text both inside and outside the card which was her own idea.

Figures 5 and 6 are representative of work done by 5 students at Whittier Elementary in the spring of 2005. I kept notes, files, photos, and save files from the programs. I had about an hour to work with each child, however some children took several sessions to finish their pop-ups, and in some cases I worked with several children at the same time. Once again, I provided help when asked, and in most cases did a quick introduction to the software at the start. There are some interesting differences to note in these four works.

Photo C represents an uncompleted work (my access to the children ended before it was done). The student spent a long time getting the mouth just as he wanted it. But he also wanted a tongue. I provided him with a book on pop-up making for children [13] which had an example with a tongue that appears to stick out when the page is opened. He copied that element and placed it on the mouth made with the tool. He gave up on trying to get eyes that would move, and was going to draw in eyes.

Photo D is another example of someone who had trouble placing eyes. He decided to make one eye in the

center, and said it was an ”evil cyclops”. Photo F is an interesting abstract design. This girl tried to make a face, but was dissatisfied with her attempts to make the eyes, and settled on a vase design, which she filled with real flowers and gave to her mother for Mother’s Day.

Another abstract design is shown in Photo E. The child making this design–who although he was in 5th grade, was 12 years old–placed elements rather randomly–unconcerned with whether they would interfere with one another; he was never interested making a face. This design was decorated by making holes with a paper punch–a decorative option that never occurred to me.

The fifth student’s work is not pictured, since he had a printed copy of the pop-up, but had not yet cut and folded it by the time we finished working with the Whittier students. I have not yet made a reproduction of this pop-up, which was an abstract design.

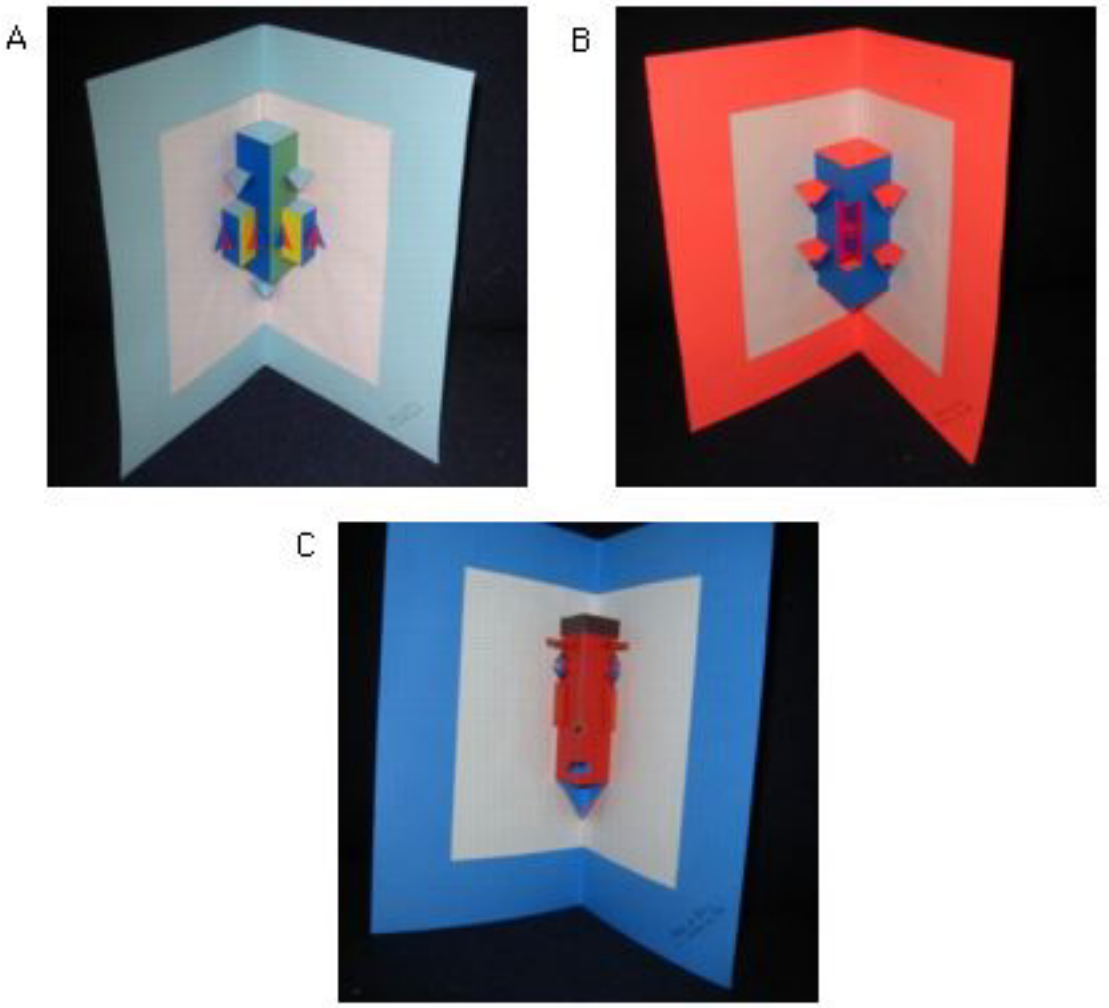

Figure 7: Three pop-ups, made by middle school children in a summer program

2.2.2 Middle school users

I had an opportunity to work with students in a summer program in the summer of 2004. I believe that they were all 13 or 14, although this was an informal session, and I did not collect any data about the students themselves. I do have files, and the photos shown in Figure 7 are of reproductions from those files.

These pop-ups are more sophisticated, orderly, and abstract. There is one face represented, in Photo C, which is very detailed–with eyebrows, ears, and a hat. This child had no difficulty in placing the eyes. In the other two cases, the children went right to abstract designs.

They did have some difficulty with cutting and folding, however. This was partly due to the paper being used, which did not crease very well, but mostly to the detailed nature of the designs, which consisted of small elements.

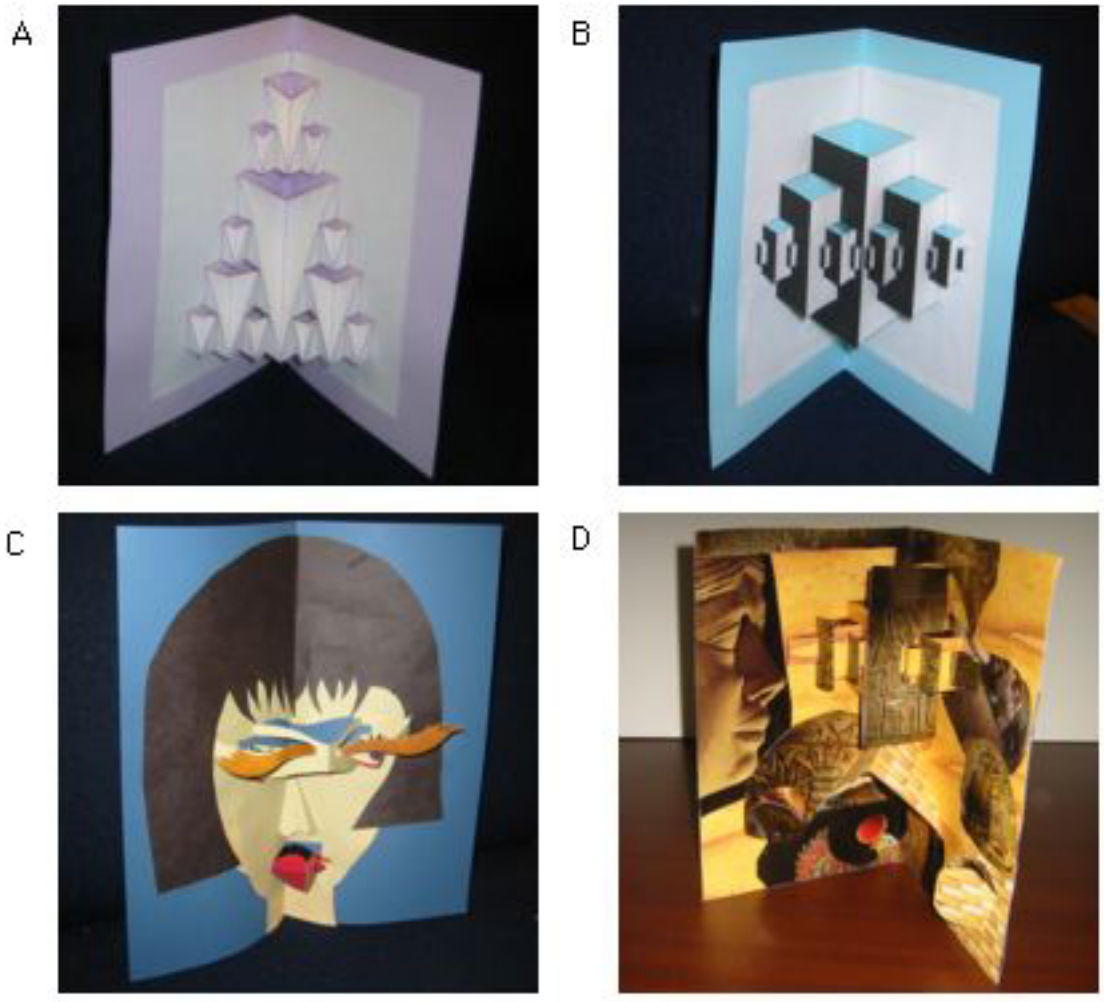

Figure 8: Four pop-ups, A and B were made by an undergraduate, and C and D by graduate students

2.2.3 Adult users

Largely in contrast to the children, I present here four designs made by adults (Figure 8). Photos A and B were produced by a DLC apprentice. He was influenced by a book on pop-ups and fractals [12]. He did not have a color printer, and this shows what can be accomplished working in black and white.

Photo C is a pop-up made by a CS graduate student. It is an example of varying the straight cuts imposed by the software, and adding additional pieces onto the design. Another pop-up (Photo D) by the author is shown, which adds additional pieces, multiple layers, and lift-up tabs.

2.2.4 Other activities

For the sake of completeness, I would like to mention some other things that have happened over the last year, as they have influenced my thoughts on evaluation.

I presented a poster at the International Conference of the Learning Sciences in the summer of 2004 [6] and have a paper accepted at Computers and Advanced Technology the end of this summer [7]. I also took part in the Doctoral Consortium at Interaction Design and Children this summer. This was a particularly valuable experience, as I focused my talk on evaluation, and received many ideas and encouraging words from the panel.

2.3 Summary of what has been learned so far

I present here a summary of the observations which I have made, particularly from user testing, that have influenced my approach to user testing. I also present some important areas in which I lack data.

First, the things I've observed:

- Most designs made by children in my experience are symmetric. The only exception was Figure 6, Photo E. The reasons for symmetric designs appear to be many. The presence of the grid is one possible influence, symmetry may be a natural design strategy, and the presence of the replicate button is a powerful inducement. Children love the replicate button.

- Kids like to make faces, particularly the 5th graders. 5 of 7 of the fifth grade students first attempted a face, and the most common question I heard was "Can I make a face?". This is also interesting in that faces have an inherent difficulty in this medium–the eyes. If they are to pop up, they must be placed on a fold. Student whose pop-ups are shown in Figure 5, and in Figure 4 Photo C discovered one solution: put the eyes on the side of the head. Figure 5 illustrates two other possible solutions: draw in the eyes, or make a cyclops. The student who made Figure 6 Photo F thought about eyes on the side of the head, but did not like that idea and finally settled on a vase design for flowers–but she wanted a face at first. Figure 6 Photo E as usual was the exception, as his style of design was chaotic and fast. This student, although in 5th grade, was 12 years old, which may be a factor.

- Actual construction of pop-ups can be difficult. More difficulty was observed with the older students than the younger–they made more intricate designs with smaller elements. Using a craft knife rather than scissors would help, but folding can be difficult as well. With the younger students, the biggest problem was their inability to see which way lines should fold. This seemed to lesson toward the end of construction, and may not be a problem over time.

- The time spent on each pop-up varies a great deal. Older students spent about 1/2 hour. Younger students often took more than an hour–mostly trying multiple designs, or tweaking one design for some time. This seems to be a personality trait–some students were more perfectionist.

- The tool was fairly easy to use. The 5th grade students required a bit more help; they were less inclined to wade right in, and wanted a demo. The most common starting problem was the necessity to start drawing an element on the fold. After about 10 minutes that problem vanished. i also noticed that students often deleted a structure and readded it rather than use change.

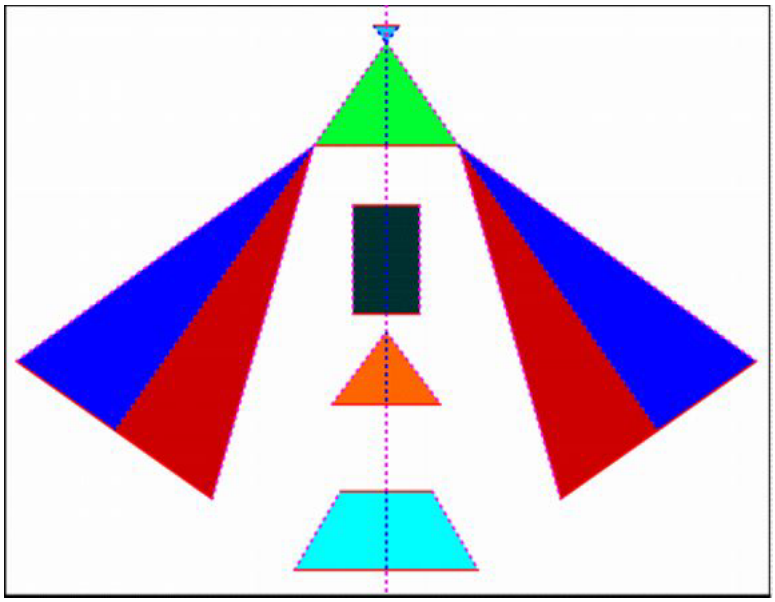

Figure 9: Pop-up with a problem.

- Overlapping or colliding elements are not flagged by the software. This was sometimes a difficulty; some students recognized these problems right away, and some were more confused. The student making Figure 6 Photo E didn't seem to care. These problems should be more obvious when the 3D Viewer is in place. There was also one interesting design by an older student which did not fold as the student had thought for an interesting reason. The large red and blue triangles were added onto the end of a fold, and not on the fold, so they do not move when the page is opened and closed. Figure 9 shows the design (I have not made a reproduction of this pop-up.) This would be obvious in a 3D Viewer that allows turning, but the artificial coloring of the current Viewer concealed the problem.

- 5th graders need more help, however they are more enthusiastic. They clambered to be the next one to make a pop-up. The older students seemed to enjoy it, but were not as excited about it, as evidenced by the fact that only a handful of students volunteered.

- Decoration additions, and addition of other pieces to the design is not common on this first pop-up, but it does happen. There was the addition by 5th graders of a tongue, writing, hole punches, and flowers. None of the children added extensions to the planes of the elements, varied the cuts into other shapes, or removed material. It would be interesting to see if this occurs with more experience. This is especially true in the case of applied elements, which see their greatest value when altered.

- Before working with the children, I had mostly designed in black and white. I was somewhat surprised by their use of color, but shouldn't have been. It was very important to them, and they often started filling areas with color before the rest of the design was done. The line drawing tools weren't used much at all,

beyond experimentation. The only pop-up illustrated here that used them is Figure 5 Photo D for the cyclops' eye pupil.

- Some of 5th graders noticed the Cartesian coordinate display and knew what it was, although I didn't see anyone using it to position things. (The Cartesian display was not available during testing with the older children.)

There are important questions and blank areas:

- One of the greatest outages in my experience is that I have only one pop-up from each student. Therefore, I have no knowledge about how the use of the tool, and their pop-up making skills, might change over time.
- Another outage is that I have no data on the cognitive processes of children when using the tool, either in terms of what skills they started with, or how they learned. Part of this is the small time I have been able to spend with each student.
- I have no experience with children attempting to build pop-ups with applied elements. These are more difficult, since they required fitting and glueing in addition to cutting and folding. Also, they require more decoration and alteration (cutting into shapes for instance) in order to make a picture. Of course, this means that they allow more variety and creativity. It is possible that use of these elements may make the process a completely different experience for the children.
- Possibly the most important interface element for feedback to the designer is the Viewer with the animation of the pop-up. Since the Viewer is not a proper 3D display yet, I do not have good information on how children will use it. They played around with it, but did not use it in any systematic way. Whether or not this will be the case over time is a big question.

3 Focusing: Producing an evaluation plan

One of the problems with deciding on what and how to evaluate this software lies with the fact that there are many directions in which one might go. While it is pleasant to have a range of choices, one can be overwhelmed by all the possibilities. In this section, I examine the directions the evaluation might go. I prioritize those possibilities, and make a plan for future work. This plan has the thesis research as its starting point.

First, I will present a summary of the possible directions that evaluation of the software could take. I stress that I am not listing the methods that could be used, rather the topics that are being evaluated. Methods will be determined once the evaluations areas have been chosen. All of these have been suggested at one time or another by myself or members of my committee. I've divided them into 6 basic categories.

1. *Supporting the craft*: Does the software support the user in learning and practicing the craft? I also include questions about how the user interacts with the software in this general category. For instance: To what level can the user be supported? What interface features support or hinder the user and in what ways? Does the software allow a transition to hand-design at some level?
2. *Entering Experience and Capabilities*: What defines a successful pop-up maker? This includes factors such as age, visualization and spatial skills. In addition, many children may have varying levels of previous experience with pop-up books and pop-up creation. They may have differing experiences and skills with tools and other paper crafts. (And of course one must ask: What do we mean by successful?)

3. *Cognitive changes and learning*: Does the use of the software foster cognitive changes or learning? There are several areas involved here. Do the students learn the constraints involved in the design of pop-ups? Mathematical, artistic, design, writing and engineering skills may be affected. One may investigate various cognitive changes in spatial reasoning and visualization skills. This differs from item 2 above in that we assume that something changes over time.

4. *Principles of design*: What are the processes which children use to design pop-ups? Are there some processes which are more successful? What is the role of pop-up constraints in the design?

5. *Collaboration and group work*: What happens when children work together on pop-ups? Because the pop-up software allows multiple copies to be more easily made, groups of children can work on pop-up books together. What are the implications for storytelling, writing, and group cooperation?

6. *Curriculum issues*: This is an area in which work has been done with traditional pop-up making or by using pop-up books in literacy ([9], [10], [8]), mathematics ([11], [12]) and design technology and art [8]. Adding software, if it supports the craft, could be useful in the classroom.

This list is ordered for a reason. I believe that there is a natural progression through these items. If I am going to use the software as a window into cognitive processes involved in making pop-ups, or to examine the social learning dynamics of group work with pop-ups, I first want to be assured that the software supports pop-up making, and I need to be aware of how it does this. I need to know what cognitive processes and skill sets contribute to pop-up making before I ask how those are changed by the experience. Working with children in evaluating their learning and cognitive skills should give me the data to formulate design principles. And it seems reasonable to be comfortable with the use of the tool with individual students before engaging in group work, and with group work before formal classroom work. This arrangement defines a long-term plan for the evaluation of both the software and the design activity.

Evaluation for the thesis is only a part of this plan. For the thesis, I concentrate on the first item: supporting the craft. This core to examining all of the remaining topics.

In addition, as mentioned in Section 2.3, there are some outages in my current experiences with children. I do not feel at this time that I can make any hypotheses about whether children learn about pop-up constraints or engage in mathematical thinking, for example. Gathering the data on supporting the craft will give me an opportunity to make more observations in these areas as well. In that sense, the thesis work that I propose here is an exploratory study.

In the next section, I will further define "supporting the craft", and lay out my evaluation plan, contributions, and thesis question.

4 New Evaluation Plan: The direction for the thesis

My plan is to make the primary object of the user testing for my thesis an evaluation of the ability of the software to support the craft of pop-up making by children. Note that I will not be comparing the tool to hand-making. My purpose is to establish that the tool supports children in learning to make pop-ups, not that it does that better than another method.

At the same time, I will be gathering information on how children approach the craft, their entering skills and knowledge, and indications of how they think about making pop-ups, with an emphasis on mathematical and constraint thinking. These observations will be used to form hypotheses about the cognitive and learning aspects of the craft for use in further research.

There is one large question that I have not yet answered, though. What is "supporting the craft"?

4.1 Supporting the craft

A good basis for work addressing children, pop-ups, and design software, is to see if the software supports the craft, and if so, how. For our purposes craft can be divided into three components: craft skills (actually making pop-ups), craft knowledge (vocabulary, knowledge of possibilities, etc.), and craft appreciation.

For each of these divisions, I list questions that will indicate whether the tool supports the piece, and how it does so. There may be additional questions that come up later, particularly concerning the software interface. I will be doing task analysis before user testing, and some additional questions may arise then. In each case, a majority of the children should show the trait in order to make it a positive result.

4.1.1 Craft skills

The first question to answer is: "Can children make pop-ups using the tool?" This seems to be answered in the affirmative so far (see Section 2.2), in that I have shown that children (from 10 years old) can make *one* pop-up successfully.

The questions that I consider should be answered in this area are:

- Do the children make 4 or more pop-ups successfully. (That is, are the pop-ups operational?)
- Do these pop-ups show an increasing level of difficulty? (Difficulty is in terms of 1) more elements 2) smaller elements 3) more use of applied elements 4) more use of combinations of elements and 5) use of asymmetry.
- Do these pop-ups show an increasing technical sophistication in terms of changes made to the basic pop-up as made with the software. (This includes cutting away of material, addition of material, changing cuts, addition of other elements that the software does not support, and decoration options beyond those provided by the software.)
- Do the children use the Viewer window to check the operation of the pop-up, and to locate colliding elements or elements that do not open properly?

4.1.2 Craft knowledge

Every craft has certain knowledge that must be incorporated by an experienced practitioner.

This consists, first of all, of vocabulary. It is a poor weaver who does not know what a *heddle* is, and a poor knitter who does not know the difference between *knit* and *purl*. This is more complicated in the case of pop-up making. There are often multiple terms for a particular element. For example, what is called a *V-fold* in Birmingham [1] is a *180 Degree Angle Fold* in Carter [2]. Therefore, I will not be looking for a particular set of terms, but rather a series of changes in which children adopt some set of words to be able to explain pop-ups.

There is also the concept of possibilities, and conversely the difficulties or impossibilities, of the craft–the "do's and don't's". The experienced woodworker knows what she can do with a particular type of wood and also the limits–how thin she may cut it and expect a certain amount of strength, for instance. A craft person may also know how to push or ignore these limits–and at this point we often call them an artist if it works.

The questions that I believe should be answered in this area are:

- Do children refer to the elements in their drawings by name–either the name used by the program, or one they have devised themselves?

- Does this change over the time that they are working with pop-ups, or become more frequent?
- Do children exhibit some understanding of the reason some pop-ups work and some don't? (This may be either expressed explicitly, or in their building actions.)

4.1.3 Craft appreciation

Often people think that *appreciation* simply means liking something. If one considers what we mean by *art appreciation* however, it is obvious that something more is meant by the term.

There are two aspects of appreciation that we need to consider. First, the term appreciation is usually used in reference to someone else's work. One need not paint to appreciate paintings. Secondly, appreciation is a *knowledgeable* enjoyment. If I appreciate Ming vases, for instance, it is assumed that I know something about them, presumably enough to tell good from bad at least. (That sadly may not always be the case, but it is the sense of the word.)

The questions that I believe should be answered in this area are:

- Are children able to describe the construction and actions of a pop-up made by someone else?
- Are they better able to do this after making pop-ups using the tool?
- Do their feelings and judgments about pop-ups change? In particular, are they backed up with pop-up knowledge?

4.2 Before user testing

In order to begin user testing, the following tasks must be completed:

- The software (Version 2.0) must be complete (see Section 2.1) and the functionality tested.
- I will have produced a reasonable set (8-10) of tasks.
- The interface must be evaluated using the techniques of task-centered design.
- Although interviews with the children will not follow a rigid script, a list of guiding questions needs to be prepared.
- Standard tests must be obtained.
- The children must be recruited and scheduled.
- The environment must be complete. (See Section 4.3)

4.3 User testing procedures

I intend to recruit 5-8 students of ages 10-13. They will work with me for 1-2 hours each week. I would like to have each student produce at least 5 pop-ups, unless they decide that they do not want to make any more (which is a data-point as well). Since I have found that a simple pop-up can take 1/2 hour, but a more complex one might take several hours, I assume that actual working time for each student would be 8-12 hours, or less than 12 weeks. (I plan about 3 months for the whole process for all the children.)

I need to consider the testing environment. Supporting a craft takes place in an environment of tools, books, and expert help. Some of the environmental considerations are:

- No other examples of pop-ups made using the tool will be provided to the students. I do not want other users of the tool to influence their designs.
- I will answer any questions that children have during the work sessions.
- Students will be allowed to do some work (decorating, for instance) at home. All computer work, and the main part of construction will take place with me during scheduled work sessions.
- Children will have access to as many professional pop-up books as I have (minus those I will use in the closing discussion (see below)) as well as any others they have access to.
- Children will have access to four books about pop-up making. They may use these to learn more, or as reference in case they wish to add something not available via the software–as in the tongue added by the 5th grader (Figure 5, Photo C). The four books are:
  - Pop-o-mania by Barbara Valenta [13]. (A beginner children's instruction book.)
  - Pop-Up! A Manual of Paper Mechanisms by Duncan Birmingham [1]. (An intermediate children's instruction book.)
  - Making Books that Fly, Fold, Wrap, Hide, Pop Up, Twist, and Turn by Gwen Diehn [3]. (A children's book on book-making. Useful if any children wish to make their pop-ups into a book.)
  - The Elements of Pop-Up: A Pop-Up Book for Aspiring Paper Engineers by David A. Carter and James Diaz [2]. (An adult's book of pop-up elements, illustrated by actual pop-ups.)
- Children will have access to:
  - a computer running the software with an attached color printer
  - a large assortment of paper of various colors, weights, patterns, and textures
  - paper engineering tools: scissors, craft knives, self-healing mats, scoring tools, straight-edges, rulers, glue, compass, and protractor
  - decorating materials: paints, colored pencils, markers, and such (they will be encouraged to add any other decorative items–feathers, googly eyes, etc.–that they think of).

The procedure for working with each student will be the following:

1. Children will be given a pre-test, and an opening interview. The pre-test will consist of two cognitive tests: a visualization test, the Paper-folding test, and a spatial test, the Card Rotation test. The opening interview will consist of questions about their prior experience with pop-ups, and cooperatively examining three pop-up books of increasing levels of sophistication. Questions will be asked to elicit comments about how pop-ups are designed and why they work. This interview will be videotaped to serve as a baseline.
2. Children will make at least 5 pop-ups in the environment above. 5 pop-ups should be enough to identify changes over time, but should keep the user tests from 8-12 weeks. They will be videotaped in order to record the working sessions for later analysis. They will be encouraged to self-explain as they go along. Photos will be made of the pop-ups (at several stages if they are complex), and the files will be saved so that they may be duplicated (since children will take the originals home.)

3. Children will be interviewed about their experience. During this final interview, they will again look at three pop-up books of varying levels of difficulty of construction (which they have not seen before) and talk about how they work. They will also be asked about the experience and what they were thinking about. This may be facilitated by showing them some of the videotape of the working sessions–especially those sessions in which they talked little about what they are thinking. (It may be necessary to show the tapes several times.) The final interview will be videotaped in order to compare the final interview with the opening interview.

4.4 What data will I collect and analyze?

The following items will be analyzed:

- Starting and ending interview videotapes.
- Working tapes.
- The photos and files for pop-ups.
- The pre-test results

This material will be analyzed, first, to answer the questions about craft support and the software from Sections 4.1.1 to 4.1.3.

As the data is viewed for the primary task of answering the thesis question about support of the craft by the software, data about cognitive changes and learning can also be isolated. In analyzing this material, the videotapes can be used to see the level of knowledge about pop-ups displayed by the children before and after. The working tapes chronicle these changes, and in addition provide some view of what craft thinking goes on. The files and photos can be analyzed to see how the children's work advances (or not.) And finally, the pre-test results will be examined to see if the children's beginning skills might influence how they work.

4.5 What contributions will this research make?

The original research contributions can be found in Appendix B. When completed, the research described here will have made the following contributions:

- It will have created a tool which may be used by children to create pop-up cards and books.
- It will have shown that constraint systems can be used in modelling pop-up action by creating a 3D image of the pop-up at each stage of opening and closing.
- It will have produced data as to whether or not the tool supports the craft of pop-up making by children.
- It will have produced data on the thinking of children during the process of pop-up making that may lead to later research.

4.6 New thesis question

The original thesis question can be found in Appendix A This research is guided by the following question:

Can a computer-aided design system using constraint satisfaction algorithms, which present pop-up books and cards as dynamic objects, be created that will enable children to design pop-ups and that will support the craft of pop-up making–its skills, knowledge and appreciation?

5 Conclusion

User testing of Popup Workshop is planned for the fall of 2005, and should take approximately 3 months.

In this paper, I have proposed a plan of research which investigates children, software, and pop-up construction, and determined that the first and most important thing to be established is whether the software supports the craft of pop-up making. I have also described a plan that identifies specific factors associated with practice of a craft, and a set of questions to be used to determine if the software to be evaluated does give that support. And finally I have presented an evaluation method to answer those questions for the software that I am building.

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Appendix A Original thesis question(from proposal)

This proposal is guided by the following question:

> **Can a computer-aided design system using constraint satisfaction algorithms, which present pop-up books and cards as dynamic objects, be created that will enable children to design pop-ups and that will add to our knowledge of the process of design and the features of software which support children's design?**

Appendix B Original research contributions(from proposal)

When completed, the research described in this proposal will have made the following contributions:

- It will have created a tool which may be used by children to create pop-up cards and books.
- It will have shown that constraint systems can be used in modelling pop-up action by creating a 3D image of the pop-up at each stage of opening and closing.
- It will have produced data about the complexity of pop-up designs produced by children, and the change in that complexity over time.
- It will have produced data about the design processes in paper engineering used by children.
- It will have produced data about vocabulary and the change in vocabulary used by children in describing pop-up books.
- It will have produced data to determine to what extent automated data collection and processing can illuminate our understanding of the use of computerized design tools.

Appendix C Original evaluation plan (from proposal)

Appendix C.1 What will I evaluate?

There are three major areas of evaluation:

- Design process as revealed by actions of the users
- Complexity of designs produced
- Vocabulary

Appendix C.1.1 Study of the design process

Novice users and expert users of this system may show differences in the way they approach the design task. Early users of the tool will probably throw away many attempts. I would expect to see more experimentation with the tool at the start of the process of learning. On the other hand, I would expect less experimentation from expert users, who know what they want. Some things to look for:

- number of redos
- number of deletes of structures

I would expect these to decline over time.

By using the recording tool, it may be possible to find other patterns in the design methods used. It should also be possible to find out which features of the software are used most often, and which not at all.

Appendix C.1.2 Study of complexity of designs produced

There are several metrics which might be used to judge the value of this application. One might be the time needed to create a pop-up. But pure efficiency and speed of production are not among the goals we have in making design tools for children. Another approach would be to investigate aesthetic appeal, or the enjoyment in creating the pop-up. However, these are hard, if not impossible, to measure.

A more reasonable measurement might be the complexity of the completed pop-ups. It is hoped that the complexity of the pop-ups made with the tool would increase for more experienced users.

The following is a non-exhaustive list of the complexity items that will be measured:

- number of structures
- size of the smallest structure (smaller is harder)
- number of different kinds of structures
- number of asymmetric structures
- the number of 'layers'–structures over others

I would expect a rough increase in each of these numbers (except the size, which should get smaller) as the users progress from novice to expert.

Appendix C.1.3 Study of vocabulary changes

Children play with and look at pop-ups, but are seldom asked to describe them. By talking to children about some pop-ups before and after either using the tool or making pop-ups by hand, I hope to discover how they learn to describe what they see. I would expect to see changes in vocabulary in particular (names for pop-up elements, for example.)

Appendix C.2 How will I evaluate?

I will require a small group of test subjects for a case study, as I will be working with them closely and gathering a great deal of data for each child. I plan to recruit 6-8 children in late grade school and middle school (4th-7th grade). I hope to have a group of mixed genders and ages.

Subjects will be working by themselves, with the researcher providing answers to questions asked. Books on pop-up construction will be on-hand as well.

Appendix C.2.1 Evaluation before the experiments

In order to obtain a baseline for the language use portion of the data, I will spend some time (approximately 1/2 hour) with each subject exposing them to pop-up books of various sorts and talking about how they are made. This discussion will be video recorded. I will also ask them to duplicate a simple single-sheet pop-up.

Appendix C.2.2 Evaluation during the experiments

Ongoing evaluation of the subjects will consist of periods of making pop-ups. During these work periods:

- The sessions will be videotaped to obtain data about the interactions between the children, the tool and the researcher, particularly their vocabulary and work styles.
- The recording tool in the environment will be activated in order to record the sequence of actions that the children use to produce pop-ups.
- The subjects will be able to keep any pop-ups they make. Copies of the files and photos of the pop-ups will be saved for later evaluation.

In all cases, the researcher will answer questions, and help the students look at the books or the software to find out how to do what they want to do.

Appendix C.2.3 Final evaluation

At the conclusion of the experiment:

- Each child and I will have a conversation about example pop-ups (similar to the conversation at the beginning of the tests) which will be recorded to compare with the initial conversation. Once again, the subjects will be asked to duplicate a simple single-sheet pop-up, which will be slightly more complicated than the pop-up used for the pre-test.
- The data from the recording tool will be examined to see what can be learned about the design process. Such information as false starts, number of changes, etc. will be evaluated.

- The pop-ups produced will be analyzed for complexity. Possible data include: asymmetries, repeated structures, number of structures, etc.
- The pop-ups made by hand at the beginning and the end of the sessions will be compared and analysed.