

Chapter 6

User Testing

Previous chapters have discussed the craft of paper engineering and the design of software to aid children in learning this craft. In order to evaluate the usefulness of this software, children were given the opportunity of working with it. Chapter 2 describes a framework not only for understanding and developing software for craft learning, but also for assessment of the learning process, and it is with this framework in mind that the user testing was planned and organized. The framework divides craft learning into knowledge, skill, and appreciation, each of which can be evaluated in a variety of ways. For example, knowledge can be assessed by questioning the craftsman about methods, tools, or even the history of the craft or its practice by others. Skill may be seen as actual tool use or manipulation of the materials or by the quality of products of the craft. Appreciation, although more difficult to judge, can be assessed by observations of the judgement of the craftsman of works by others, or the use of such observations in her work.

This chapter begins with a summary in Section 6.1 of early informal use of the software and how this led to the final design of the formal user tests. Section 6.2 describes the methods used in the formal testing, including the test environment and procedures, and the methods of analysis. The users are described in Section 6.3. The outcome of this testing is compiled in Section 6.4, and reflects the results in the areas of knowledge, skills and appreciation as well as the user's reactions to the software, additional pop-ups constructed outside of the test sessions, and what they did with their pop-ups after the testing. Finally, Section 6.5 reflects more deeply on the use and limitations of the testing methods.

Several of the appendices may be helpful to the reader and will be referenced in this chapter. Appendix D contains a list of tools, materials and books that were available to the users during user testing. The questions asked of users during the first and last sessions, and in the email follow-ups are listed in Appendix E. Photographs of all of the pop-ups produced by the users along with a brief summary of each test session are included in Appendix F. Finally, Appendix G presents a series of tables summarizing the use of elements and decoration for each user's pop-ups, along with the inspiration for pop-ups where that is known.

6.1 Informal Testing

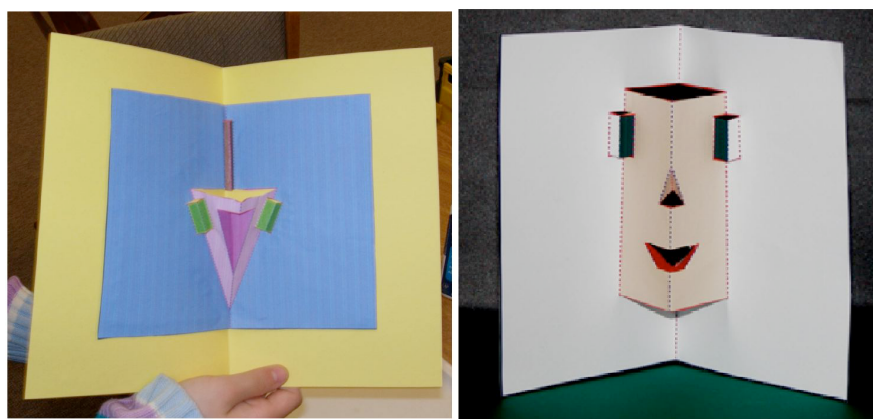


Figure 6.1: Pop-ups made during the informal studies: These pop-ups were made by 5th grade girls using an early version of Popup Workshop.

Before describing the formal user testing that is the primary subject of this chapter, some discussion of early informal user tests should be undertaken for three reasons. First, this testing helped to guide the design of the software, particularly during the transition from Version 1.1, used during informal testing, to Version 2.0, which was the version used for formal user testing. These changes made in Version 2.0 are more completely described in Section 5.2 and include a new Viewer Window with better 3D representation of the pop-up and the addition of 180° elements. Second, the informal testing showed that children were interested in using the software,

could use the software, and were able to cut and fold the resulting pop-ups to produce finished pieces. Finally, this informal testing guided the design of the final formal user testing. In particular, it became obvious during this process that testing would require users within a wider range of ages, making more pop-ups over a longer period of time, using a greater range of element types and a with a more complete pop-up making environment available.

Those readers desiring more information on the early testing, including photos of a variety of the pop-ups produced and a description of the software at Version 1.1, should consult Hendrix and Eisenberg [47] and Hendrix [46].

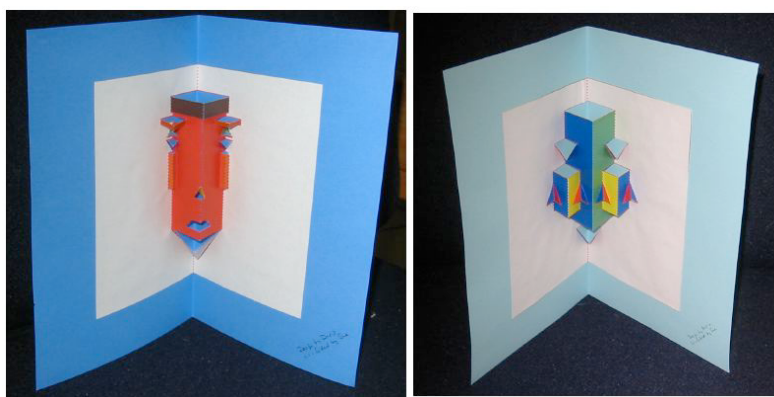


Figure 6.2: Pop-ups made during the informal studies: Two pop-ups made by middle school children in a summer program.

Early tests were done with 5th graders at an elementary school in Boulder, Colorado. The tests were conducted with several students who had been chosen to participate in a test of Hypergami (see Eisenberg [28]). This was a classroom setting with a small group of children, five of whom worked independently to produce one pop-up each. Two of these are shown in Figure 6.1. One other 5th grade student from Eagle, Colorado also made one pop-up. In addition, five middle school students enrolled in a summer program made one pop-up each. Two examples are shown in Figure 6.2.

Several pop-ups were also made during this period by adults using the software. An undergraduate intern made six pop-ups, a graduate student made a single pop-up, and the researcher

produced several. Two of these are shown in Figure 6.3. These pop-ups were primarily created to determine the limits of the software, identify bugs, and test on both Windows and Macintosh operating systems.



Figure 6.3: Two pop-ups Made in Informal Studies: Pop-ups made by (left) undergraduate and (right) graduate level college students.

6.1.1 Observations of Children During Informal Testing

No specific questions were asked of participants in the informal testing, but the users appeared motivated to make pop-ups and interested in the results. The 5th graders were more enthusiastic than the older, middle school users judging by the numbers of volunteers, and the excitement shown by the younger children.

The users had no difficulty with the program itself. The younger users needed a bit more instruction, as they seemed reluctant to simply plunge in. The most common problem was that the cursor needed to be placed near a fold when adding a new element. But after a few minutes this difficulty disappeared.

Actual construction of the pop-ups presented no great problems, although very small elements were difficult to fold. This difficulty was seen more with the older users, as they tended

to make more complex designs with smaller elements. Part of the folding difficulty arose because the tools available to the users were limited, and included no craft knives or tools to score the folds. The paper used was printer paper rather than card stock which, while generally easier to fold, is too thin for many pop-ups, particularly 180° elements which require more stiffness. Since there were no 180° elements available in the early version of the software, printer paper did not present a real problem, but needed to be backed with a stiffer paper after the pop-up was made.

Younger users experienced more difficulty when deciding which way to fold an element. This improved as the work proceeded, and it might be assumed that over time the difficulty would disappear if the users made more pop-ups.

A "face problem" was noticed. Users (particularly the 5th graders) wanted to make faces. Often the first thing said by the user was, "Can I make a face?" 90° elements can be used to make faces, but a problem can arise with the making of the eyes. Since elements must be placed on a fold, eyes can be placed on the side of the head or nose, but not (if composed of pop-up elements) between the nose and the side of the face. In addition, the decorative materials provided to these users were limited to pens and pencils, and this added to the problem. (For more information on this face problem, and how the children solved it, see Hendrix [47].)

A number of other observations were made. These included the fact that non-adult users did not alter the shape of cuts in the designs or add additional material to the pop-ups. The only exception to the latter was the addition of a tongue to one mouth. This was done with the help of an instruction book that the researcher happened to have with her at the time. When working with the software, the children commonly used fill colors, but the line drawing tool was almost never used. In virtually every case the designs created were symmetric. There were no 180° elements available, which limited the type of designs that could be produced. The 5th graders noticed that the x- and y-coordinates of the cursor were given, but none used them to position elements.

When working with the software, the users did not use the Viewer Window very much. Since the representation could not be rotated and was not a particularly good 3D model of the final pop-up, it meant that colliding elements might not be found, and indeed were not found in

at least two cases. Also, one user produced a design that did not open as elements were on an extension of a fold rather than the fold itself. The viewer did not clearly show the action, or non-action in this case, of such a pop-up.

Finally, the desirability of making multiple copies became evident. Although the users took their copies home, the researcher was able to make a copy from the exported files to study later.

6.1.2 Influence of the Informal Tests

The most important results of the informal user testing led to software changes that addressed the limited set of available elements and the usefulness of the Viewer Window.

No information could be gleaned from those tests about how users might handle 180° elements. These are important, as they constitute the major components of commercial pop-up books. These elements require gluing pieces onto the base page, thus adding complexity. The absence of 180° elements tended to limit the types of pop-ups that were being created, so two basic 180° elements were added as a result of this testing.

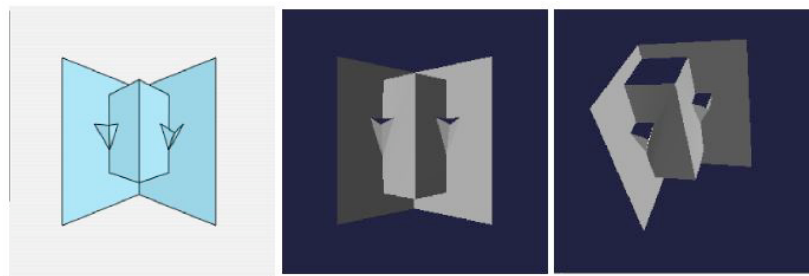


Figure 6.4: Comparison of the Viewer Window in software versions: The Viewer Window in Version 1.1 (left) was statically oriented and colored to suggest shading. The Version 2.0 Viewer Window provides a more realistic view of the pop-up (center) and rotation (right).

The initial Viewer Window proved to be a problem. First, the orientation of the pop-up was fixed, allowing opening and closing of the pop-up but not rotation, which is needed to fully examine the pop-up for element collisions. Second, the 90° elements were shown, but not the areas behind them. That is, the users could not see the holes created by the element. Third, the

shading on the representation was simply made by shading all left planes with one color value, and all right planes with another value, rather than having a light source produce true shading of the pop-up. The differences between the Version 1.1 and the Version 2.0 representation of the pop-up are shown in Figure 6.4. The shading problem and the lack of rotation were solved by adding the Java3D libraries to the code base. The "cutting out" of the planes beneath a 90° element proved more difficult to correct, as planes needed to be mended when an element was changed or removed. This was solved by marking the original points of the plane so that the original plane could be restored.

One of the features that became obvious in reviewing the informal testing was that it included users only 10 years old and older. The motivation shown by the 10 year olds, the ease with which they learned how to use the software, and their ability to manipulate the paper, even without the best of tools, was an indication that younger users could participate in the activity, and this needed to be tested.

The informal testing occurred in unstructured environments, either classrooms with several users working at one time or, in the case of adult subjects, totally unobserved. This limited the researcher's ability to observe the users at work in any detail and there was no ability to engage with a single user or record the activity without interruptions. Formal tests were therefore designed to accommodate single users with videotaping for detailed study.

The fact that only one pop-up was produced per user meant that it was not possible to observe changes over time. For instance, it has been noted that the users did not add attached planes or alter the shape of cuts in their pop-ups, which begs the question about what might have been seen with additional pop-ups. As another example, some users had difficulty at first in knowing which way to fold a given fold-line and this seemed to lessen with time. There was no indication about how this difficulty might further change with more pop-ups. For these types of reasons, formal testing was planned to have users make at least four pop-ups.

It has been noted that one of the users in the informal tests added a tongue to a mouth in his pop-up following an example in an instruction book that the researcher happened to have. For

the most part, however, users did not have access to any supplementary materials. In addition, the limited set of tools and lack of stiffer paper constrained the results. It was decided that for the formal user testing, the environment would include a set of books, both commercial pop-ups and instruction books, an array of tools, various colors of card stock, and decorative materials. This environment is more completely described in Section 6.2.1.

6.2 Formal Testing Methods and Environment

As the previous section indicates, early studies with Popup Workshop uncovered several deficiencies in the software and testing methodology that needed to be addressed. First, a more capable version of the software was required that would allow the users to make 180° as well as 90° elements. A more functional Viewer Window with the ability to rotate the 3D representation of the pop-up was seen to be needed as well. The 2.0 version of the software provides both of those features.

Second, recruiting users from a greater range of ages, in particular younger children, would help to establish the usefulness of the software for not only upper elementary and middle school aged children, but for those in the early grades as well. Those users needed to participate over longer time periods and make several (at least four) pop-ups in order to see not only if their interest continued but if their skill and knowledge levels changed over time.

Third, formal testing would require a work environment which included a sufficient set of good quality hand tools, a large variety of materials, and reference materials which could support pop-up creation, stimulate the user's appreciation of the pop-up world, and allow for the observation of that appreciation.

Fourth, it was decided to have some type of pre- and post- testing assessment tasks to specifically evaluate users' knowledge gain.

Finally, it was determined that videotaping the user sessions would allow for a more thorough analysis of the results.

All of these things were accomplished for the formal testing. The following sections de-

scribe the environment, the methods used, and how the data were collected and analyzed.

6.2.1 User Sessions and Environment

Popup Workshop as tested consisted not only of the software (see Chapter 5), but the complete environment in which the testing occurred. Children had access to reference materials consisting of both commercial pop-up books and how-to books on pop-up making. The pop-up books were chosen to represent a variety of styles, complexity, and paper engineers. The how-to books ranged from Valenta [123] which is suitable for very young children to Carter and Diaz [14], a book which includes examples of, and constraints for, a wide variety of elements. Diehn's [26] book on bookmaking for children was available as well, in the event that children wanted to make books out of their designs. Children were given time during sessions and encouraged to look at books.

The complement of available tools included craft knives and a cutting mat for use by the 3 older children, while the 6 and 7 year olds used scissors only. An embossing tool was at hand for scoring along folds to allow a smooth fold, something that was not available for early informal trials. This was particularly important here as the paper provided was card stock which, while difficult to fold without scoring, is more appropriate for pop-ups, particularly 180° elements, which must be sturdy enough to stand up from the page. A range of art materials was present as well, ranging from markers, crayons and colored pencils to googly eyes and sequins. Appendix D is a complete list of the references, materials, and tools available to children in this environment.

All users worked singly with the researcher during sessions in order to allow them to concentrate on their work and to have the full attention of the researcher. The researcher occasionally made suggestions to the users or provided guidance when asked for help, but for the most part children worked through their designs alone. Sessions lasted one hour for the youngest children, but the older children occasionally worked for up to two hours in a session.

6.2.2 Pre- and Post-testing Assessment

The data obtained from the sessions included the pop-ups users made and user comments about pop-ups and Popup Workshop. In addition, tests and surveys were made at the beginning and end of testing and a follow-up questionnaire was sent to users several months after the testing was completed. The pre- and post-testing activities were designed to understand how the children thought about the way pop-ups were constructed, their vocabulary changes, their opinions about the software, their prior experiences with pop-ups and paper crafts in general, and what they thought about the testing, their pop-ups, and the software at a later point in time.

During each user's first session, several questions were asked in order to get acquainted with the user and to gauge each user's experience with pop-ups. This process was informal and took the form of a conversation, although the same topics were always included. During the final session, the questioning was oriented toward the child's experience with the software and the pop-up design process in general, including a retrospective of their previously-made pop-up designs. Lists of topics for both question sessions are available in Appendix E.

In addition to these conversations, two standardized cognitive tests were given to each child, with the first half of the questions of each presented during the first session, and the second half during the last session. These tests were the Card Rotations Test and the Paper Folding Test described in Ekstrom, et. al. [30]. The Card Rotations Test, designed to test spatial orientation, presents a shape, and asks which of eight other shapes shown represent the same shape rotated, or the shape turned over (mirror image) and rotated. The Paper Folding Test, purportedly a test of visualization ability, shows a piece of paper being folded and one or more holes being punched through the folded paper. The person taking the test chooses which of five drawings represents the paper when unfolded. These particular cognitive tests were chosen as they use the mental manipulation of paper shapes, a valuable skill when envisioning a functioning pop-up.

It was suspected that these tests would probably not show any changes in these cognitive areas over the short time in which testing was done. However, they were cognitive areas that could

prove important to skill acquisition in pop-up making, and it was thought that the tests might be an indication of the potential of each child at the very least. In addition, the time investment (3 minutes per half-test) was minimal. The test results are further discussed in Section 6.3.3.

The most important element of the testing was a discussion about actual pop-ups conducted with each child. The same three pop-up books were looked at in both the first and last sessions. During these sessions, the child was asked to talk at length about how one of the pop-ups in each book worked and how it was made. The same pop-ups were used in both sessions with each child. This discussion provided the bulk of the data concerning knowledge and appreciation of pop-ups.

The three pop-up books chosen were representative of three levels of pop-up making, ranging from a pre-school or early elementary school book to an example designed with older children and adults in mind. They range in difficulty of the design and complexity of their pop-ups, as well. These books were previously mentioned in connection with the frequency of occurrence of pop-up elements in Section 4.1.2 as they serve as good examples of the range of commercial pop-ups available. The particular pages of each book examined in the user testing are described here and were picked because they contain interesting uses of the elements that are available in Popup Workshop. While 180° elements such as tents and v-folds were common, 90° elements are rare in commercial pop-up books. The only example included in these pages was a beak with moving arms attached to it.

First, *Snappy Little Farmyard* [109] is a fairly simple, but cleverly made pop-up, one in a series of books for young children. The page selected to be analyzed by the children (see Figure 6.5) contains both a tent (the covering over the pig mechanism illustrating a fence and gate) and a v-fold for the pig. The v-fold is hidden and cleverly folded and braced to give an upward motion to the pig.

Second, *Haunted House* [85] was chosen for its use of interesting mechanisms. It is aimed at children of elementary school age, but is more complex than *Snappy Little Farmyard*. The page selected shows, among other things, a gorilla. Two tents make a fireplace grate and furniture. The

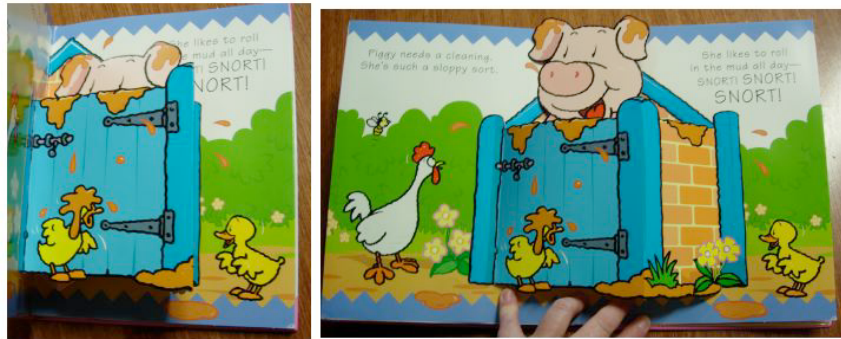


Figure 6.5: Assessment pop-up 1: The pig from *Snappy Little Farmyard*. A tent forms the fence and conceals the mechanism that raises the pig, which is a folded v-fold.



Figure 6.6: Assessment pop-up 2: Gorilla page from *Haunted House* contains tents, a beak and attached moving arms. The motion of the gorilla's arms during opening is shown.

gorilla has a moving arm mechanism placed on a beak built into the larger tent.

Raggedy Ann and Andy and the Camel with the Wrinkled Knees [41] is hard to categorize in terms of the age of children who might read it. In some sense, it is an art book for adults. However, the story is presented in the book by way of gatefolds and would be enjoyed by a young reader. The pop-ups are quite complex but are built largely from simple elements with many attached planes. The page used in the testing has two large pop-ups in addition to small pop-ups in the gatefolds. At the rear of the illustration a v-fold lifts an attached plane representing animals and bushes through the use of an extension (which could be considered a tent). At the front, three



Figure 6.7: Assessment pop-up 3: Scene from *Raggedy Ann and the Camel with the Wrinkled Knees*. Two views are provided to show the front and back parts of the scene. The front part consists of an angled platform made from two v-folds supporting a field of flowers. Figures are attached to the v-folds and slotted through the flowers. In the back, a v-fold lifts an attached plane.

characters are attached to two v-folds that combine to make an angled platform. These v-folds are hidden by a table-like sheet of flowers.



Figure 6.8: Assessment comparison pop-up 1: *Alice in Wonderland: A Pop-up Adaptation*, paper engineered by Robert Sabuda [13]. This version of the tea party is modeled after the original Tenniel drawings for the book, and shows a very strong 3D representation.

Some subjects are more frequently encountered in commercial pop-ups than others. Animals, for instance, appear in many of the pop-ups provided for the children in the test environment, including 5 books on dinosaurs alone. This set of pop-ups also included two versions of *Alice in Wonderland* [13, 12]. As Figures 6.8 and 6.9 illustrate, these books are very different in style and in the construction of their pop-ups. During the last session of user testing, all but one of the children were shown the pop-ups of the tea party from both books and were asked to compare them in order to elicit any thoughts they had on their differences and which they liked best, in order to determine if some indication of their ability to appreciate the pop-ups made by others would emerge.



Figure 6.9: Assessment comparison pop-up 2: *Alice in (pop-up) Wonderland*, paper engineered by James R. Diaz [12]. This tea party has a very cartoon-like style, and the table is modeled in a foreshortened, semi-3D manner.

After the user testing was complete with all subjects, a follow-up questionnaire was sent to each. The questions were sent on August 7, 2007, approximately 4 months after the last session with the last user to finish, and almost 11 months after the last session with the first user to finish. This was done via email, since two of the subjects had moved and were unavailable for face-to-

face meetings and email was available to everyone. All of the subjects responded (or rather, their parents responded with their answers.) The purposes of the follow-ups were primarily to look for long-term effects of the testing and to find out what had happened to their pop-ups. Questions were asked about their favorite pop-ups, whether they had done any pop-up making since the user tests, and what had become of the pop-ups they made. The full list of questions is reproduced in Appendix E.

6.2.3 Data Collection and Analysis

The data collected during user testing included videotapes of all sessions. These were converted to DVD, and notes with times for key events were made for all the DVDs. In addition, transcripts were made of important parts of session, particularly for the questions and pop-up book analysis done during the first and last sessions. The transcripts were used to examine the vocabulary used for the elements.

The children took their pop-ups home when they were completed, but photos were taken of each pop-up to provide a persistent record. These photos and descriptions of each session with each child are collected in Appendix F. In addition, the software design for each pop-up was saved in both XML and JPEG formats. The features of each pop-up were counted and categorized and the results are summarized in the tables of Appendix G. These features include the number of each type of element used, the total number of levels, the symmetry, decoration used, additional elements added by hand, and where the ideas came from for each pop-up.

Finally, the cognitive tests were scored, and the answers to the follow-up questionnaire were compiled.

6.3 The Users

An attempt was made to recruit children by distributing posters to schools and placing them on bulletin boards. In the end, however, the users came from families of colleagues (Daisy, Ursula and Richard) and from a family with an older sibling who had taken part in another study

in our research group (Peggy and Emily).¹ Daisy and Richard are sister and brother. Peggy and Emily are fraternal twins.

Table 6.1 lists age and gender information for the children. The children fell into two age groups with Ursula and Richard in the young group (6 years of age when testing started) and Daisy, Peggy and Emily in the older group (11 or 12 years old when testing started). Peggy and Emily turned 12 during testing, so the two groups will be referred to as the 6 year olds and the 12 year olds.

User	Age	Gender	Birth-date
Daisy	12	F	January 1994
Ursula	6	F	September 1999
Richard	6	M	December 1999
Peggy	11	F	December 1994
Emily	11	F	December 1994

Table 6.1: A summary of information about the users. Users are listed in the order in which they started participating.

There were some differences observed in the user tests relating to the children's ages that should be mentioned. First, when cutting, the 12 year olds had access to craft knives while, because of safety concerns, the 6 year olds were limited to scissors. Since the scissors make it difficult to cut slits in a sheet of paper, the researcher sometimes helped by starting cuts on slits for the 6 year olds. Second, the 6 year olds were less inclined to experiment with the software when first starting to use it. They preferred to have the researcher demonstrate or help them through some of the software's functions first. The 12 year olds all started to experiment without any guidance. Third, both of the 6 year olds made a pop-up by hand at the start of the sessions. This seemed to put them at ease, allowed them to demonstrate their paper skills (particularly in the case of Richard, who knew how to make a step), and satisfied their desire for immediate contact with physical materials. This last was most obvious in the case of Ursula, who seemed to prefer working with paper to working with the computer. The 12 year olds seemed more

¹ Pseudonyms are used throughout for users.

interested in the software when they first began testing. Finally, the 6 year olds could not read, at least when they began testing. This meant that they were not using the help or tool tips available in the software, which may explain some of their hesitation in using the software at first. In addition, they could not write text on their pop-ups. Richard did ask the researcher to write some captions on his pop-ups for him. In general, the 12 year olds needed less guidance or help, which is not unexpected.

6.3.1 Users - Data About Sessions

Table 6.2 summarizes the beginning and ending dates and amount of testing for each user. The number of sessions ranged from 5 to 13. The 6 year olds were limited to one-hour sessions but the 12 year olds had a few longer work periods. Richard had the fewest sessions and spent the least time in testing as his family was preparing to move. Emily worked for the greatest number of sessions and the most total time as she extended her testing sessions to finish the book on which she was working.

Table 6.2 also helps to establish the time required for a child to make a pop-up. The users spent 43.2 hours in testing sessions, making 42 pop-ups, which would point to a bit over 1 hour for a pop-up. However, the total pop-up making time was less than 43.2 hours, as most of the first and last sessions were spent on pre- and post-testing activities and discussions of their backgrounds and the software. And, of course, children are capable of spending some session time looking at books and off-task. Taking this time into account, the true average time is probably closer to 45 minutes per pop-up. But pop-up making is a highly variable activity. Emily's moose (see Figures F.3, F.4, and F.5) or Daisy's owl (see Figures F.32, F.33 and F.34) are examples of pop-ups that required a great deal of time to make. The time required varied greatly by child as well. Ursula averaged almost 2 pop-ups in one hour, mostly because she did not like to spend much time on the computer, but wanted to print quickly and get the paper in her hands. Peggy spent a great deal of time designing her pop-ups and adding additional handmade elements, and therefore took 8 sessions to make 4 pop-ups. Although the time to make a pop-up varied greatly,

it was a reasonably quick process and one which could fit into a class period in most cases. This underscores pop-up making's utility in the classroom.

User	First Session	Last Session	No. Sessions	Hours	No. Pop-ups
Daisy	07/03/06	09/29/06	7	8.5	7
Ursula	07/07/06	11/17/06	8	7.5	14
Richard	08/02/06	10/06/06	5	4.5	7
Peggy	11/05/06	02/04/07	8	7.0	4
Emily	11/05/06	03/24/07	13	15.7	10

Table 6.2: A summary of information about the user sessions. Users are listed in the order in which they started participating along with the number of sessions, total time spent working on pop-ups in hours, and total number of pop-ups made.

6.3.2 Users - Prior Experience

In terms of prior experience, all the users had done some sort of crafts before. Daisy had made a doll-house from cardboard and wood. She had also participated in a previous study in our research group which involved making an automaton (a dragon) from wood. Ursula had worked with paper a great deal, creating her own projects. For instance, she made a large (about as large as she was) unicorn from folded and glued paper. Richard liked to draw, and mentioned this as his favorite part of school. Peggy said that she made crafts as gifts for the holidays or when her sister (Emily) wanted to make something with her. She indicated that Emily was “the crafty one”. Emily sewed stuffed animals, wove, and was taking an art class and working on an oil painting at the time.

More specifically, three of the children had made some sort of pop-up before. Richard demonstrated his style of pop-up making (steps with attached planes, see Figure F.15) during his first session. Although he made steps, he was unaware of beaks. The opposite was true of Peggy and Emily. They often made small pop-up cards to use on presents that utilized beaks. They had not used steps before.

In addition, Ursula was aware that pop-up making was possible for kids. She mentioned

that a friend had made a frog using a beak. She wasn't certain how to do this, however, and this was the first thing that she asked to see during the user testing.

All of the children had previously used computers although the type and amount of use varied among them. They all mentioned using them to play games, with Richard and Peggy seeming to be the most dedicated computer game-players. For drawing, Ursula had used Kid Pix, and Emily and Peggy had used SketchUp.

User	Paper Folding			Card Rotations		
	Start	End	Sum	Start	End	Sum
Daisy	-1.00	6.25	5.25	52	47	99
Ursula	0.25	4.00	4.25	15	24	39
Richard	1.00	1.25	2.25	9	6	15
Peggy	3.25	3.00	6.25	40	56	96
Emily	7.75	7.50	15.25	47	43	90

Table 6.3: Cognitive Test Results: User scores for the Paper Folding (Visualization) test and Card Rotations (Spatial Orientation) test. Half of each test was administered before and half after the user testing sessions.

6.3.3 Users - Results of Cognitive tests

Table 6.3 summarizes the results of the standardized cognitive tests administered to the children, the Card Rotations Test and the Paper Folding Test. The first half of each test was administered in the first sessions, and the second half in the last sessions. This is the suggested way of using these tests, and they are divided into two parts for this purpose.

Standardized tests were included as part of the testing for several reasons. First, such tests have been used previously by other researchers in the area of craft software user testing [28, 8], and they have reported useful insights from such tests. Second, the time involved was minimal, three minutes per test per section. Third, it was anticipated that the tests might be used to classify the users into groups exhibiting differences in pop-up making ability. Although the tests were administered both before and after the craft work, the small amount of time that the children would be working should not produce any change in such basic attributes, so no change was

expected. Rather the two separate administrations of the tests were considered a check on the results, which should be similar. The tests were therefore administered in order to see if those children who did better on the tests were better able to learn the craft.

These particular tests were chosen because it was thought that spatial orientation might be an important area of cognition in pop-up making and, as the shapes created in making pop-ups often rotate in place, the Card Rotations test might be particularly apropos. Similarly, the Paper Folding test explores the ability to spot the result of several operations performed on a piece of paper. Being able to visualize such results seemed logically related to the ability to make pop-ups.

An important caveat relates to the ages of the users. The tests are not specifically designed for children, so the ages of the participants might invalidate the results. Certainly, comparing the 6 year olds directly to the 12 year olds would be inadvisable, as one would naturally expect age alone to create differences in scores. There are no specific scores which might be expected from users of any age, so that one cannot look at a score in isolation, but must compare scores between the users.

Daisy and Ursula had much lower scores in the first test administration of the paper folding test than in the second administration. This was probably in part due to nervousness and confusion over the directions, as the paper folding test is a difficult task. Otherwise, the scores do not seem to show any measurable improvement between the first and second administrations as expected. The tests certainly showed a difference between the two age groups, in that the total scores of each 6 year old were below the total scores of any of the 12 year olds.

Of note is Emily's very high score in the Paper Folding test which was over twice the score of any other participant. Emily had done the most craft-work, including art, was probably the most dedicated reader of the group, and wanted to be a writer when she grew up. In addition, Emily made the most pop-ups, continued user sessions the longest, and made a connected story from her pop-ups. These facts say nothing about the cause of Emily's high Paper Folding Test score. It is impossible to say if Emily's visualization score is high because she has done so many crafts, or that she does crafts because it is something at which she excels.

There is also a distinct gap between the test scores of the 6 year olds, with Ursula clearly out-scoring Richard. However, it is hard to make any claims about these two children. Both children had a history of making paper objects on their own. Richard did not make as many pop-ups, but he was moving and had to leave the testing. Also, Richard showed little interest in the cognitive tests, and tended to stop working on them before time was called.

In short, whether because the tests themselves are meaningful or because of the small sample size, the standardized tests produced no results that were of use in understanding the learning of paper engineering by children.

6.4 Results

In Section 2.3, a framework for the study of craft was developed and the analysis of the results presented here is based on that framework. These results are divided into areas related to the competencies of knowledge, skill, and appreciation in order to assess the performance and craft learning of children in the user testing as detailed in Sections 6.4.1 to 6.4.3.

Since these results relating to the craft competencies may not always address specific parts of the software, Section 6.4.4 is devoted to the remarks and answers to questions from the users about their experiences as well as observations about their use of the software. In addition, since the users provided feedback after the testing, parts of this section discuss the answers to the follow-ups, particularly as they reveal the later fates of the pop-ups made during the study, and additional pop-ups made after (or in one case, during) testing.

6.4.1 Craft Knowledge

In Section 2.3.1, craft knowledge was identified as one of the fundamental competencies of craft. Assessing knowledge is relatively straightforward, as tests or discussions with the learner can uncover the quantity and quality of the learner's knowledge. During the first and last sessions the users spent time examining commercial pop-up books and discussing how they worked in order to provide some insight into their understanding of pop-up action.

To more easily assess this knowledge, a small subset of pop-up craft knowledge was chosen for evaluation. The particular subset chosen for evaluation was the identification and naming of pop-up elements, which is both important and observable. Elements (see Section 4.1) are the basic building blocks of pop-ups and it is reasonable to observe how children identify elements in order to arrive at an understanding of their learning. Consistent names were used for elements in both the user tests and the software. This allows a comparison to be made with the names the children used during their discussions of the target pop-ups.

Pop-up	Daisy	Ursula	Richard	Peggy	Emily
<i>Farmyard</i> Tent	"tent fold thing"	"tent"	-	-	"tent thing"
<i>Farmyard</i> V-fold Variation	P, "v-fold"	"v-fold"	-	"weird v-fold"	"bent-up v-fold"
<i>Haunted House</i> Tents	"tent fold"	-	"tent thing"	"step and another step"	"tent" (says step then corrects)
<i>Haunted House</i> Beak with Moving Arm	"triangle"	"v-fold"	-	"v-fold"	"beak v-fold"
<i>Raggedy Ann</i> V-folds with Platform	"v..." ,P	-	-	"two v-folds"	"v-folds"
<i>Raggedy Ann</i> V-fold with Attached Plane	P	P	-	"v-fold and a little step"	"v-fold"

Table 6.4: Element Names in User Tests: The element names used by each child in the final session are shown in quotes. "P" indicates that the child used the software controls to indicate the type of element instead of using the name, correctly identifying the element in each case. "-" indicates that no element name was used.

During the first session, children did not use element names, although they could describe the construction and motion of pop-ups. They had not been exposed to element names yet via the program, and this demonstrated that, most likely, they had not encountered these names anywhere else. Children, even the younger children, could explain pop-ups without a vocabulary of element names. They often used gestures to show the motion, and talk about folds and connec-

tions. As an example, here is Richard (6 years old) explaining the *Raggedy Ann* pop-up (Figure 6.7) in his first session.

Richard: Hm. Ok. *[He looks under the flowers.]* When this closes...um...when this closes *[closes the book]* it pushes them down and these things *[fingers on front v-fold]* go down like...go down like that. And then when you open it, it *[hands on flowers]* goes up, and then it causes it to go up *[runs his fingers up the characters]*.

Researcher: Mmmm. How about this one back here *[points to animals]*.

Richard: Hm. It's um..this one, how it is, is it connects *[indicating connection between v-fold and attached plane]* and it's kind of like mine *[The pop-up with steps that he has just made]*.

This is quite a complicated pop-up, but Richard spots the important parts: the v-folds supporting the platform, the character's connection with the v-folds, and the connection between the v-fold and the attached plane in the rear portion of the pop-up. Richard was the most adept of the children in this first session, but not unique. Peggy, for instance describes the same pop-up:

Peggy: *[closes, opens, looks at it from the back. Opens and closes again, touches characters. opens and closes.]* So the dolls in front here, they're folded so like they have a little tab under them, like it goes like that *[makes right angle with two flat hands.]* and so, when you close the book. they just fold down, on top of the tab, so it's really a pretty simple pop-up, but like it's really cool, and there's slits in the flowers so it looks like they're standing in the flowers. And then these guys *[in back]* are basically just a fold, and when you close it they fold in and when you open it, the page opens, and they're kind of forced to stand up. And then the bush is attached to this.

Researcher: And the bush is attached here.

Peggy: But you notice that they're more 3D, because that way it's not just standing on its own.

The last observation of Peggy's, that the separation of the bushes into two parts makes the scene more 3-dimensional, is a particularly cogent one.

During their last session, children did refer to elements by name, and Table 6.4 summarizes the results. In some cases, the children noted the type of an element by pointing to the software control on the computer screen, and this has been noted where it occurred. This was seen in the

cases of Daisy and Ursula because the program was running during the time they talked about the pop-ups, and was therefore convenient. But in most cases the elements were identified by name.

Some of the children identified more elements than others. There are three possible reasons for this. The first is time on task. Emily spent far more time working on pop-ups than the other children, and did the best job of identifying elements. She showed a great improvement in her ability to describe pop-up action during testing, and it is interesting to compare her reaction during the first and last sessions to the *Farmyard* pop-up (Figure 6.5). In the first session, Emily was reluctant to talk about the pop-up, and in fact did not describe it other than to talk about the number of pieces:

Researcher: So how does this one work?

Emily: Some really complicated folds. [*She looks down in the tent.*]

Researcher: OK, So first of all, how many pieces has it got?

Emily: Like, two or three million.

Researcher: Oh, not that many!

Emily: One. two. three. four?

Researcher: Well, OK. We've got this one [*points to tent*] of course. What about the inside?

Emily: I think...this looks like one piece [*points to the v-fold*] and this [*points to the pig*] is one piece.

Researcher: Yeah he is, he's glued on there, isn't he?

Emily: So it's like 3 pieces.

Her description in the final session was brief, yet more detailed and accurate:

Researcher: So how does that one work?

Emily: It's a tent thing, and yeah, there's a v-fold under there. A bent-up v-fold.

Richard had the shortest time of any of the children to work on the pop-ups, and he displayed the least vocabulary change. Part of this may be due to a second indicator of whether vocabulary is learned: the elements used during testing. Until his last pop-up, done after the description of the pop-up books was complete, Richard had not made a v-fold, and most of the

example pop-ups were based on v-folds. Another example is Daisy, who had made no tents. She did use the word “tent”, but called it a “tent fold”.

Finally, the younger children (Ursula and Richard) in general used less of the element vocabulary than the older children. This may be in part related to their inability to read the help text and tool tips in the software that were a vehicle for vocabulary learning in the 12 year olds.

The most common mistakes made with element terminology was switching the names of elements within the categories of angled and parallel elements. This can be most clearly seen in the *Haunted House* pop-up, where the base of the moving arm (a beak) was called a v-fold, and the tent was called a step. In all cases where an element’s name was given incorrectly as another element’s name, the switch was between 90° and 180° element names. There were no examples of children switching the names between the parallel and angled elements. It may be the case that the angled/parallel distinction is more important than the 90°/180° distinction. Also, since the software draws the shape of the elements the same for 90° and 180° elements, with angled elements drawn as triangles and parallel elements drawn as rectangles, the software itself may reinforce this similarity for the users.

Identification of elements by name occurred at times other than just during the post-testing activities. For instance, Ursula correctly identified several v-folds during her 5th session while looking at other pop-up books. Of particular interest is the answer given by Emily to a question in the follow-up email several months after testing. She was asked if she had made any pop-ups since the test sessions and answered, “I made a castle with a knight in front of it. The castle was three layers of v-folds going straight up. the knight was also a v-fold.” The terminology had remained with her. It appears that all of the users learned at least some element names during their sessions, and therefore that their knowledge of pop-up vocabulary increased.

Another indicator of increasing knowledge about paper engineering that was not specifically tested for was the users’ ability to select an appropriate element or set of elements for a particular purpose. This is harder to measure, and opens up the difficult question of what is “appropriate”. Perhaps a better way to describe the process is to refer to the ability of the users

to obtain the effect that they wanted. This can be a difficult target in paper engineering, even more so with movement than shape, and there were numerous cases in which the design did not work out as the users wanted. One example, was Peggy's inability to make a cloud that would move over a sun that is discussed in Section 7.3.1. However, in other cases the desired effect was achieved, usually in one of three ways: by experimentation, by locating an example, or the by using a previously-used element. Experimentation, in particular the use of prototypes, is most clearly illustrated by the pull-tab Emily constructed on her *Moosey McMooseMoose* pop-up. (See Section F.5 and in particular Figures F.32 through F.34.) Experimentation, of course, is not so much a demonstration of knowledge acquisition as a vehicle for it. The knowledge gained about pop-ups is more clearly demonstrated by the fact that children often were able to know where to find an example or instruction on how to produce the effect that they wanted. For instance, Daisy, in making her *Owl*, remembered a pop-up of a Toucan in *Very Lazy Lion* [116] and used that body as a model for her owl. Children also reused certain elements or combinations of elements, especially when they liked their first use of them. For example, Ursula enjoyed her *Turtle Gymnast* (Figure F.10) enough that she used it as a model for her *Fat Upside-down Bunny Gymnast* (Figure F.11) and showed much more confidence in constructing the second v-fold figure. Peggy liked the v-fold as a platform enough to use it in three pop-ups. Users thus showed an ability to use similar construction in later pop-ups.

6.4.2 Craft Skill

The skill competency was defined in Section 2.3.2 as that portion of craft learning that must be practiced, that cannot be learned from observation or written directions. This can include the use of tools and materials as well as the process of design itself.

Skill can be assessed either by watching the performance of a craft, or by looking at the resulting craft objects. Section 6.4.2.1 focuses on the pop-ups made by the users to see if they show changes in skill. This object approach to the question of skill development was chosen in part because this method presents some interesting problems in how to analyze pop-ups, objects

which have not previously been examined in such a way. It also allows all of the pop-ups to be examined at once, an undertaking of much greater difficulty with direct observations of the user's actions, considering the amount of data generated by videotaping. In Section 6.4.2.2, some additional observations of tool and material use are made. It is possible as well to use the observations of a more limited set of children during their work, and in Chapter 7 this will be the focus.

6.4.2.1 Skill Assessment Through Craft Objects

Because of the modular construction of pop-ups, with the elements being the components, it is possible to organize the pop-up data around the general categories of element use and alteration, decoration, and symmetry.² Some of these categories revolve around pop-up complexity. The first category of such measurements is the type and number of each element, not only elements created in the software, but those added by hand. Second are alterations made to the elements, such as changing a cut line, removing portions of an element, or extending an element plane. A third measure of complexity is the number of levels in a pop-up. Figure 4.12 illustrates how the levels in a multi-level pop-up are determined and Tables G.1 through G.5 indicate both the highest level created in software for each pop-up, as well as the highest finished level if additional levels were added by hand. Fourth, symmetry is another characteristic to examine in children's pop-ups and Tables G.6 through G.15 indicate the symmetry of each pop-up in four categories. First, the design in software may be symmetric and remain so when the pop-up is complete (S). One such pop-up may be seen in Figure F.1. Second, the original design in software may be asymmetric (A), and remain so when complete. Figure F.9 is an example of such an asymmetric design. Third and fourth, the original design may be symmetric, but the card may be turned on its side when finished, making it vertically asymmetric as viewed (St) or may be altered by adding decoration or extra elements such as attached planes (Sd). These last categories are

² In examining the pop-ups produced by each child, Appendix F with the photos of the pop-ups should be consulted. In addition, Appendix G contains tables with the construction details of each pop-up for each child. Tables G.1 through G.5 detail the numbers and types of the elements used and the number of levels, while Tables G.6 through G.15 contain a summary of alterations made to elements, additional elements not made in software, decoration methods, symmetry, and where the idea for the pop-up came from.

not mutually exclusive. One pop-up which exhibits both of these asymmetries is shown in Figure F.15. Finally, decoration can be evaluated, whether computer coloring, coloring with markers, crayons or colored pencil, and items like sequins or googly eyes added to the pop-up.

Most of these data are simply indicative of complexity. An important question to ask is whether complexity equals skill. The answer, of course, is that it does not. However, complexity often requires skill. It is true that one element, properly made, simple, and perfectly adapted to the design can be evidence of great skill in paper engineering. It would be remiss to concentrate on the above data and ignore the quality of work that goes into a pop-up, or the applicability of a given element to the task. The goal here is to navigate between the Scylla of measurable but possibly meaningless data and the Charybdis of subjective views of quality to reach some understanding of how the skill of the users has changed.

Beginning with a general discussion of the work and progression of each child, focusing on the features of the pop-ups produced and how they changed over time, will establish the general pattern of work for each user. Rather than visiting the users in order of testing, age will be used. The 6 year olds are described first, followed by the 12 year olds. These views of each user are followed by general observations culled from looking at the users overall.

Ursula, one of the 6 year olds, was less concerned with the software in general than the other users were. Her aim was usually to use a few (sometimes only one) element, use no computer coloring, and print as quickly as possible. She wanted paper in her hands rather than a design in software. Ursula began in what might be described as her "bunny period". Most of her designs revolved around bunnies and turtles. She discovered the utility of the v-fold with her third pop-up, and returned to that element several times. Ursula did not make many multi-level abstracts, and therefore her pop-ups tended to be one-level for the most part. She made only one asymmetric pop-up, *Bunny and Castle* (see Figure F.9), and it was surprisingly good in all respects, with two 180° elements and an attached plane. Ursula had a long recess in her testing sessions between session 6 and session 7. When she returned for her two final sessions, she had left her bunny period behind and produced the most interesting abstract of her sessions, the

Totem Pole (see Figure F.14). While this was not the most complex pop-up she had made in terms of number of elements or level, the decoration and quality of her work seemed to have taken a major step.

Richard had the fewest sessions. He also came into the testing with the best ability to make pop-ups, as he demonstrated in his first session with the *Alien and His Ship* (Figure F.15), made by hand with steps and attached planes. Although his test time was short, Richard proved an excellent pop-up maker. He did not use a large number of elements, nor as many levels of elements as, for instance, Ursula did. But he produced only one truly symmetric pop-up, using flaps, decoration and rotation to vary the form of the pop-ups. He also, in *Volcano Camp* (Figure F.17), added an entirely free-form element, the lava flow on the mountain, which he allowed to fold naturally when the page was closed. This pop-up was also interesting in that Richard had a clear idea of what he wanted the finished pop-up to look like. His last pop-up, the unfinished mountain scene (Figure F.19) captured the essence of a very complex commercial pop-up from which he was inspired. Overall, Richard's pop-ups were showing an increase in both complexity and quality.

Peggy made the smallest number of pop-ups, only four, but her work was very detailed and very complex from the start. She showed interest in the mechanisms involved, using an angled platform made from a v-fold in her second pop-up (and repeated in her third and fourth), and a wheel in her last. She spent more time with the "how-to" books than any of the other children, and usually let the form of the elements dictate the subject and design. All of her pop-ups displayed at least 2 levels, and she used a mixture of symmetry and asymmetry. Peggy did a great deal of hand-work, which was the reason she produced fewer pop-ups, and the results were more complex as a result.

Emily was the storyteller of the group. Her pop-ups fit together naturally into a book, with each new character being related to the last. Because of the large amount of time she spent, 13 sessions, Emily showed the most development of any of the users. Her first pop-up was a simple 90° face. She worked with only a few elements in any given pop-up, which she chose carefully

to illustrate the character she was working on. But she also went beyond the software and used a pull-tab mechanism, a coil, and added hand-made v-folds to make ears for her elephant. In addition, she used a v-fold as a platform, probably taking the idea from her sister. Her work was largely symmetric on the computer, with later decoration (such as attached planes and flaps) adding asymmetry. Only her last two works were asymmetric. Emily showed a great increase in skill, primarily illustrated by *Bart the Elephant* (see Figure F.36) in which she added two layers of v-folds for the ears. Emily showed a love of bright colors from the start, and her use of color in all her pop-ups was very striking. She was, after her first pop-up, the user who brought the most colored paper to her pop-ups³.

Daisy was unusual in that she made mostly abstract or semi-abstract pop-ups using 90° elements. Her first pop-up contained the greatest number of elements of any that the children made in the testing. However, she found that the small beaks that comprised most of the design were very hard to cut and fold. There is, therefore, an immediate change in her pop-ups beginning with the second one. From that point on she used fewer, larger elements, except for her last pop-up that was produced when she was able to handle smaller elements. She tended to have a high number of levels because of the general form of her pop-ups. The one exception is her *Owl*. This pop-up came from a suggestion by the researcher that she try to illustrate a story. The result was a very realistic, and very large, owl. The most interesting feature of the owl was the talons, which were not foldable. This made the owl into a paper sculpture rather than a true pop-up. Daisy was the only user to produce such an object. An advance in her skill is shown by looking at her last pop-up. Although this was another abstract with 90° elements, it is much more interesting in design than her first, and a cohesive whole.

Each child used each of the elements provided by Popup Workshop at least once. Table 6.5 summarizes element use over all of the children and is drawn from the tables in Appendix G. That 90° elements were the most used is not surprising as they are the easiest to produce.

³ Both Peggy and Emily are featured in Chapter 7, with a more detailed look at the first pop-up and one later one that each made.

However, all of the children did use 180° elements on occasion, and even the youngest had no trouble making and designing with them. Ursula, in particular, was fond of the v-fold.

Perhaps the most surprising fact, and one which shows the users' ability to move beyond the software, is the addition of hand-made elements. For the development of skill in paper engineering, it is highly desirable that children be able to augment the designs that the software can produce and learn to modify and add elements of their own. Most of these elements were attached planes, but in several cases flaps (particularly used by Emily and Richard), wheels, coils, and pull-tabs were added as well. There were also a few non-standard elements, such as the lava on Richard's *Volcano Camp* or the talons on Daisy's *Owl*. The last were actually non-foldable additions.

Aside from Daisy, who used many elements in her first pop-up and then retreated to fewer because of the cutting and folding difficulty, there was no consistent change in the number of elements used by the children over time. This may be because the children were beginning to focus on getting the appearance and motion they wanted rather than just building in intricacy.

User	Beaks	Steps	Angled Steps	V-folds	Tents	By Hand
Daisy	31	29	15	3	3	6
Ursula	14	7	4	4	3	10
Richard	2	6	1	3	1	14
Peggy	1	5	2	5	4	8
Emily	7	7	4	4	1	40
Total	55	54	26	19	12	78

Table 6.5: A summary of the elements used by each child. The elements made by hand were attached planes, flaps, wheels, pull-tabs, coils, and non-standard elements.

Once again, there is no particular progression in the number of levels for any one user. The most levels designed with the software was 4 in Daisy's final pop-up (see Figure F.6). This observation is useful in future planning of software for pop-up design, as it indicates that the number of levels will probably be small in most cases.

The data also show that children appreciate symmetry. Of the pop-ups made in testing,

20 were in category S (symmetric), and 16 in Sd or St, while only 6 were clearly designed to be asymmetric. Since two of the asymmetric designs contained no computer created elements, it is quite possible that symmetry arose as much from the use of the computer as from the children's sensibilities. After all, the elements are drawn symmetrically to begin with, and children did not use the Change feature as much as might be expected. The Replicate feature also encourages symmetry. Asymmetry seems to be a product of skill development, however, as more designs which deviate from strict S type were seen toward the end of testing.

From the examination of the artifacts, there is no one measure in all of the children that indicates the development of skill in pop-up making. However, when each user's work is examined, it is clear that skill had increased. Each child learned to use some element (a v-fold for Ursula) or combination (the v-fold platform in Peggy's case) to add to their repertoire of design techniques. In addition, all of the children added elements and attached planes, modified elements, and in other ways went beyond the bounds of their software designs, which shows a certain development of the feeling for how pop-ups are constructed.

6.4.2.2 Observations on Tool and Materials Use

Pop-ups are not usually made from the common papers employed in children's crafts. Regular printer or drawing paper is too thin to stand up properly, especially for 180° elements. Figures 6.1 and 6.2 show pop-ups made of 90° elements with a backing of construction paper added later that illustrate that printer paper is sometimes usable. Construction paper folds poorly and cracks, so it is also not particularly suited to the craft. Pop-ups are usually, and most successfully, made from card stock or other stiff paper that can be hard to fold. Card stock was provided to the users for their pop-ups as a default paper, and the children had no difficulty in working with it. The only other paper used was the base page for Daisy's *Owl*, which required larger sheets of paper for which she used scrap-booking paper that resembled a night sky.

All of the users modified elements or added their own elements, including attached planes as well as flaps and other element types. In the process, they picked up a number of skills related

to the use of materials. First, most seemed to understand that material added to extend the plane on an element worked without problems. Examples are Ursula's *Bunny and Castle* (see Figure F.9), and Emily's *Howard the Giraffe* (see Figure F.30). Second, they learned that material could be removed from an element, as in Richard's *City* where a door was cut in the building. Third, and related to the last principle, is that cuts can be altered when making elements. For instance, the slits cut for 90° elements do not have to be straight and the same is true for the unglued edges on 180° elements. Ursula discovered this with her alteration of the tops of v-folds in several pop-ups for instance, such as her *Bunny's Picnic* (see Figure F.8) where the v-fold is cut into the shape of the bunny. And finally, at least Emily and Richard discovered that folds could be made in handmade elements simply by closing the page and letting the fold happen in the right place. Richard used this technique in *Volcano Camp*. These are all important ways of dealing with paper in the production of pop-ups, and were acquired naturally by the children as they were needed.

While many tools are common to paper engineering and other paper crafts, pop-up making differs from those crafts in which children usually engage in one particular tool, the tool to score folds. Because of the use of stiff card stock, in order to make folding easier and allow the folds operate more smoothly, the fold needs to be scored before being folded. This is done by pressing a tool that is neither too sharp nor too wide along the fold to compress the fibers of the paper. The children were provided with two tools for this purpose, a ball-point pen that was out of ink and a dual-tip embossing stylus. They all rapidly learned to use the tool, reached for it automatically, and scored all of their folds, preferring the embossing stylus. They quickly learned that unscored folds would cause difficulty. The older children were much more adept at this process; the younger children would often score folds irregularly or too softly.

6.4.3 Craft Appreciation

In Section 2.3.3 appreciation was identified as the ability of a craftsman to assess the work of others, to knowledgeably enjoy the results of craft, and to use the work of others as a guide. In this section, two criteria are used to assess the work of the children in the user testing sessions for

changes in appreciation. First, the source of their ideas is identified in order to determine if they used other pop-ups to aid in their designs. Second, their comparisons of two different commercial pop-ups representing the same scene are investigated.

Artists and craftsmen usually begin their exploration of a craft by copying the work of others. At the very least, their desire to make objects comes from seeing the work of others. This may be done in a piecemeal fashion, seeing a particular method, material or design used by another and incorporating it into their own design, the particular shape of a handle on a pot, for instance. It may also be done in an effort to make an accurate duplicate of the original, often as a part of training to master techniques and materials as they work on the development of their own style. Such admiration for and imitation of the work of others is part of the growth of appreciation, and among other things drives the ability to develop one's own style within the tradition and limits of a craft. The question of where the users in this study got their ideas is therefore a question of their development of appreciation as they sifted the information available and chose how to design and construct their own pop-ups.

The ideas for the subject and those for execution of the pop-up are usually separate. For instance, in making her *Owl* (see Figure F.5), Daisy chose the subject from a book that she was reading at the time, but for its execution she looked at several pop-up books featuring birds, went to the Web to obtain pictures of owls, and changed the design as she worked on the computer. For many of the abstract pop-ups, the design developed out of play with the software and a name was attached to the result later. An example of this is Ursula's *Totem Pole* (see Figure F.14). Overall, most of the inspiration for the execution came from pop-up books, how-to books, the Popup Workshop software, and the work of other test subjects. One particularly interesting result of the user's time spent with the software was that more pop-ups developed from experimentation with the program than from any other source. Out of 42 pop-ups, 24 derived at least some inspiration from play with the software. This suggests that access to the software can influence the way that children learn the craft by reversing the usual process. That is, in the early stages of experimentation with the software, the idea of the subject of the pop-up is put on hold, and the

user plays with the mechanics of a design that may or may not gain identification with a subject until later.

While there are many resources available to the budding paper engineer, three that were used extensively by the users were paper engineering instruction books, professional pop-up books, and other children. One example influenced by instruction books is a pop-up made by Peggy, who spent a lot of time looking at the instruction books, and particularly at *The Elements of Pop-up* [14] where one of the elements featured is a wheel with a moire pattern. Peggy wanted to make a wheel like it, and this became the basis for her pop-up *Sun and Tree* (see Figure F.25), to which she also added a slider that she learned to make from *Pop-O-Mania* [123].

Richard did not use v-folds in any of his pop-ups until the last session. During his final look at the sample pop-up books, he was very taken with a pop-up in *Raggedy Ann* showing a mountain and soldiers that was made from 3 nested v-folds. He spent a lot of time examining it, and as there was some time left in the session, tried to copy it. The resulting pop-up was not completed, but Richard captured the essentials of the form in three nested v-folds, and began cutting them to make a mountain (see Figure F.19).

Finally, users also built upon the work of each other. The original methodology did not envision interaction between the children, but with two pairs of siblings, this was inevitable. In fact, it happened with each sibling pair. Richard's sister, Daisy, was fond of making abstract designs, and Richard made the abstract pop-up in Figure F.17 for her, as an obvious copy of her style. The technique of using a v-fold as a platform for a folding structure was developed by Peggy, who used it in three pop-ups. Her sister Emily picked this up for *Tap-dancing Cow No. 47* (Figure F.31). If the children were working in groups, it is likely that much more of this interaction would have occurred.

The second criterion used to assess appreciation was the users' comparisons of the two *Alice in Wonderland* tea party pop-ups shown in Figure 6.8 (referred to here as *Tea Party 1* [13]) and in Figure 6.9 (*Tea Party 2* [12].)

Ursula found it difficult to compare the pop-ups and needed prompting to look at them

carefully. This was a difficult task for a 7 year-old.

Ursula: I like this one. [*Points to Tea Party 1*].

Researcher: OK. Why do you like that one?

Ursula: But here I like this one. [*Points to Tea Party 2*].

Researcher: Why?

Ursula: I don't know.

Researcher: Well, let's see. What's different about them?

Ursula: This one [*Tea Party 1*] doesn't have any floppies like this one does [*Tea Party 2*]. [*She plays with flaps.*]

Researcher: Yes. There's no flaps on this one. This one does have this, though [*indicating gatefold*]. That goes up on the side. But what about the table? Is anything different about the tables?

Ursula: Uh.

Researcher: And...

Ursula: This one is more of a box [*Tea Party 1*] and this one isn't [*Tea Party 2*].

Researcher: Yeah, that one's not as much of a box, is it? And...how about the characters, how about the people, there's her, and there's her [*indicating Alices*] and the rabbit...

Ursula: She's more white. [*Indicating Tea Party 2 Alice.*]

Researcher: She's more white, yeah.

Ursula: And she's more ? [*Tea Party 1 Alice*]

Researcher: Think she's unhappy?

Ursula: She looks more like a human [*Tea Party 1*].

All of the children were able to point to some obvious differences: the box form of the table in Tea Party 1 and the more cartoonish nature of the drawing in Tea Party 2. And they were unanimous in choosing Tea Party 1 as their favorite. It appears that realism, characters that look like the illustrations they have seen before, and a more 3D appearance won out over an exaggerated style.

Daisy: Well, this one [*Tea Party 1*] the table kind of [*pause*] I like this table cause it goes up and you can see everything. This one [*Tea Party 2*] it kind of goes out. [*Moves her hand over it.*] I like that too, but I

like this one because you can see it all. And you can actually look inside and there's tea [*indicates cups on Tea Party 1*] and this one [*Tea Party 2*] they're just pop-up things [*indicating tea cups on Tea Party 2*] and if you look like that [*peers over*] it's like nothing.

Appreciation is more difficult to assess than the other competencies. It is slow to develop, and depends on the development of both knowledge and skill for its base. However, it appears that children evaluated and copied from other pop-ups and users enough to suggest that they were in the process of developing this competency to some degree. They were also able to pick out specific features of two pop-ups with a common subject to allow some comparison between them and to pick the one they preferred. This further indicates the development of appreciation in the users.

6.4.4 Other Observations

So far, assessment of changes in the user's craft abilities has been done using the competencies of the craft framework developed in Chapter 2. A few additional observations that do not fit precisely in this framework should also be made. The motivation of the users is an important measure as well. Observations of the users' reactions to and use of the software are notable, as are the additional pop-ups made concurrent with and after the testing sessions that demonstrated a high level of interest in the craft. Finally, the follow-up emails determined fates of pop-ups produced in the sessions and illuminated aspects of the social importance of children's craft items.

6.4.4.1 User Motivation

All of the users showed excitement about making pop-ups. Ursula's father indicated that she was talking about how interesting it was, something not so apparent to the researcher due to Ursula's shyness. Emily continued for extra sessions as she was working on a book and wanted to finish it. Richard had begged to do pop-ups in the testing when he saw his sister Daisy get involved. Even Peggy, who was not interested in continuing past the originally agreed eight sessions seemed taken with her last pop-up, and commented that it was nice to pretend to be a kid again.

Motivation was particularly apparent when the subject of the pop-up interested a user. One excellent example was Daisy's *Owl* (Figure F.5). Daisy had been doing mostly abstract or geometric face pop-ups when the researcher suggested she might want to illustrate a story. Daisy brought a book she was reading to the next session, *The Capture* by Kathryn Lasky [65]. The characters are owls, and the book's inside cover is illustrated with several species of owls. Daisy spent sessions 4–6 working on the owl, a total time of almost 5 hours. When completed, the owl was nearly 2 feet in width, and colored with colored pencils (a very time-consuming medium.) She said:

Daisy: *[After attaching the body]* Yes! Yes! And I'll probably have it on my wall, like in a place where it looks down at me! *[Holds it up in the air]...*

Daisy: *[After attaching the body and holding it up again.]* That is creepy and that is cool!

A further indication that the children were motivated and enjoyed doing pop-ups was that one of them made additional pop-ups concurrent with the sessions, and that several made pop-ups after the conclusion of the testing.

Emily made a pop-up book as a birthday present for her father, bringing it in to show at one of the sessions. Figure 6.10 shows two of the six pop-ups from the book. They are interesting in that the first is an asymmetric step, and the second is a series of steps, all made by hand. Emily had said that she had made cards for holidays before, but only using beaks, and we discussed this during her final session:

Researcher: So you said that you had only done beaks before.

Emily: Yeah. Sometimes I'd just like stick on some, but they didn't really pop. They just popped because the pressure of the paper.

Researcher: So you made the book for your dad, and I noticed it had some other things in it, did you get that idea then from doing this? *[the user testing]*

Emily: Yeah, very much.



Figure 6.10: Two Pop-ups Made at Home by Emily: Emily made a book of pop-ups for her father's birthday. These are two pop-ups from the set of six.

Several users also continued to make pop-ups after the sessions had ended. In the email follow-ups after testing concluded the following question was posed, and these answers were received:

Have you made any more pop-ups since? If so, describe the neatest one.

Daisy: No, I havent made any more, but I want to.

Ursula: *[Her father sent pictures of the pop-up in Figure 6.11, top.]*

Richard: Yes, but not using the software. *[And his father added: But he did make one with it. He makes lots of them for cards mostly sometimes just fooling around.]*

Peggy: no i haven't.

Emily: Yes. I made a castle with a knight in front of it. the castle was three layers of v-folds going straight up. the knight was also a v-fold.

Of the five users, three had continued to make pop-ups. Three of Ursula's pop-ups are shown in Figure 6.11. Two are Christmas cards, and are interesting in that they show changes from her pop-ups made during testing. This is to be expected as her artistic tastes and abilities had changed. This is particularly evident in the two pop-ups she made using Popup Workshop, in which she has integrated the 90° elements with the subject matter and used asymmetry (bottom left in the figure) with the package under the tree.



Figure 6.11: Three Pop-ups Made at Home by Ursula: The pop-up on the top was made without Popup Workshop, while the pop-ups below used the software.

6.4.4.2 Software Usage

There were two important features of the program, the replication feature and the pop-up viewer, that provide important functionality and information to the user. The replication feature allows the production of symmetrical designs, which is important when making abstractions of 90° elements. Replication makes it easy to produce abstractions such as Daisy's three pop-ups shown in Figure F.6 and these would be much harder to do by hand. Every child made at least one design using the replication feature. Daisy concentrated almost all of her effort on such

designs and mentioned replication specifically in her discussion of the program:

Daisy: ...And then also I like this, [*replication*] because

Researcher: I noticed you used it a lot.

Daisy: like if you do this you don't have to like [*pause*] instead of having to go like [*pause*] well instead of having to

Researcher: Replication you're talking about?

Daisy: Yeah, like try to make another one is really hard. You just go like this. And then also it shows you where you need to cut and that's really hard too.

There is no doubt that the tool was useful to the children, and influenced the type of designs made. However, it was found that the replication tool was hard to use at first. The problem is that there is only one situation in which an element can be replicated. There must be a matching fold on which the new element will sit, and the original element must not have been previously replicated. For instance, an element on the centerfold of a page has no matching folds and can therefore not be replicated.⁴ It took a bit of time and experimentation for the children to see what elements could be replicated and what elements could not. Part of this problem arises from the fact that the replication button puts markers on every corner of every element, not just those that can be replicated. If only the elements which could be replicated were marked, learning to use the tool might be easier.

Another important component of Popup Workshop is the pop-up Viewer Window in which the user can see the design dynamically in 3-dimensions. Users loved to play with the motion of pop-ups in the viewer and especially enjoyed twirling the designs. There were occasions when users were able to use the viewer to detect element collisions in a design, but those times were more rare than expected, and they seldom used the viewer to experiment with the form or placement of elements.⁵ For instance, one might expect a user to change the angle of the attached piece on a v-fold to see the change it makes in the elevation of the piece, but this was rarely

⁴ As an example of this case, in Figure 5.5 the large centered step cannot be replicated as there is no matching fold. Also, after replicating the smaller steps, they cannot be replicated again.

⁵ For two exceptions, see Chapter 7, which describes Peggy's use of the viewer to look at her design upside down while she was making it, and Emily's detection of collision.

done. It is possible that the testing period was not long enough for users to reach the point where this experimentation would have become common. Certainly the users changed elements less than had been expected. Still, the children enjoyed using the viewer like a game, and were quite pleased when they made it display a pop-up incorrectly, as can happen when the constraints lead to a wrong solution. Emily was one:

Researcher: So how about the 3D part, the viewer, did you find that helpful or not, I know you love to use it.

Emily: It was kind of helpful, but I think it's fun. It's funny when it messes up.

Researcher: *[laughs]* Which it does.

Emily: But its funny when you go like this *[twirling it fast]* cause it looks like one of those weird Cubism art things.

Several of the users mentioned that they would like the Viewer to have the same colors as the Editor. Peggy mentioned that as a possible change:

Researcher: So what didn't you like about it? I mean, I'm sure there are things.

Peggy: Yeah probably the fact that there was no color for this *[3D viewer]*.

...

Researcher: So, how about the 3D part? Did you use that very much, or feel that you, did you, did you look at that a lot?

Peggy: Well, I definitely looked at it, um, Cause I definitely like to see, I definitely like that you can see how it's going to look before you print it out, instead of printing and going "Oh, I didn't want it to look like that." Cause then you're sure you know that it's going to look like so and so, and it's going to have a weird thing growing out of it's nose. It's always nice to know.

6.4.4.3 Social Dimensions of the Pop-ups

Children's craft items represent more than the labor put into them, as a look at any parent's refrigerator will demonstrate. They are given as gifts, displayed in the home, kept sometimes into adulthood and beyond. I have a table that my mother bought unfinished for a quarter when she

was a child and finished herself. I will undoubtedly hand it on to the next generation. Children's crafts as social currency has been studied before [28]. Such items are more than art:

...from the aesthetic perspective, art objects have a purpose of their own—the unique ability of producing new visual experiences, feelings, and ideas. If a picture drawn by a child is cherished for this reason and not for what it looks like, the object is valued as a symbol of love or personal relationship, but not as art. [20]

Examples of pop-ups as social currency were seen during user testing. Richard made a pop-up in the style of his sister as a gift for her (see Figure F.17) and Ursula made a flag pop-up to give to her teacher on Veteran's Day (see Figure F.13). One of the informal test pop-ups was used as a Mother's Day card (see Figure 6.1, left). The maker's plan was to put flowers in the vase shape on the card. And finally, Section 6.4.4.1 describes the pop-ups made by Emily for her father, and by Ursula as Christmas cards.

An interesting question to ask is what happened to the user testing pop-ups. The children took them home after they made them, leaving only photos and computer files for the researcher. The answers to this question will reflect the children's feelings for the pop-ups, as this is a part of their social dimension. In the email follow-up, they were asked two questions to evaluate these feelings:

Which one is the one you like the best? How do you feel about it and why?

Daisy: I liked the owl, because it was so realistic and cool.

Ursula: *[sent picture of her and Turtle Gymnast]* I really like it because it's really cute.

Richard: The volcano one. I liked it because it was a big huge mountain and I like mountains.

Peggy: the one i like the best is the one where the sun had the wheel so it could change colors. i like it because all the other ones were just plain old pop-ups, this one was unique.

Emily: i liked my dancing cow best. I liked it because it was cute, difficult-ish, and had two parts. i also liked my moose because of the sliding smiley-face thing.

Which one is the one you like the least? How do you feel about it and why?

Daisy: I liked them all, I had no bad ones

Ursula: [*sent picture of white abstract*] I think it's just a design-not really interesting.

Richard: Can't remember

Peggy: i like the table one the least. I feel like i didn't really make it as good as it could have been and it really wasn't interesting.

Emily: I think I liked the mouse the least. I just don't think it was as fun to make as the others.

Users liked the pop-ups that took the most work (the moose smiley-face and the wheel for instance), were different, or contained subject matter that particularly appealed to them.

As to what happened to the pop-ups:

What has happened to the pop-ups you made? For instance, did you give any away, put them in a book, lose them, display them, put them up in your room, throw them away?

Daisy: I put some up in my room [*in Germany*] but some I put in storage in Boulder

Ursula: First I displayed them around the house [*for several months*]. Now they're displayed in my room.

Richard's Father: He packed them away with his stuff when we moved to Germany, some got tossed

Peggy: I have kept my pop-ups, I know where they are, first i put them with my magazines and then i gave them to my mom.

Emily: I think I put them in book form, but then i lost them. :(

Peggy and Emily's Mother: I have [Peggy]'s and they are in her 'memorabilia' box. [Emily]'s are stored in her room (she is not the most organized person in the world) and we plan on putting them into a complete book form.

For the most part, the pop-ups were kept, either on display or packed away safely. They have become items of social currency, as shown by the comment by Peggy and Emily's Mother, who has ensured that they are kept.

Pop-ups made by children provide excellent examples of the emotional and social investment children can put into the craft objects they create. Providing value to both the maker and

the receiver, they are easily produced, take the form of cards which are common gift items in our culture, and are easily stored and kept.

6.5 User Testing in Context

Stepping back from the results, this section looks at the user testing from a more personal perspective in order to evaluate the strengths and limitations of the methods used. I begin by looking at the influence of the design of the informal testing on the design of the formal testing to see if the suggested changes were reasonable, and to compare the results of the informal and formal tests. I then look at some of the methods and results of the formal tests to arrive at some understanding of how both could have been made better, including the thorny dilemma of the influence of the researcher on both the children and the results.

In Section 6.1, the early informal testing and its influence on the design of the formal user testing and software enhancements was described. In general, this influence was a positive one. In terms of the software, the more realistic viewer with its ability to rotate the image of the pop-up, and the addition of 180° elements were positive additions. Users in the formal testing used the viewer more often than during the informal testing since they liked to rotate the design, and consequently located collisions more easily. All of the children used the 180° elements, even the 6 year-olds.

More interesting perhaps were the informal testing's influences on the formal testing's methodology and the selection of its users. First, younger children were included in the formal testing. This was very useful in revealing that children as young as six could use the program, albeit with a bit more adult assistance at the start. Since young children are very interested in pop-ups, their ability to use the software broadens its utility to the entire range of school children's ages. Second, with a longer series of testing sessions and with more pop-ups made by each child, it was possible to see how the children gained knowledge, skill and appreciation—something that was not possible during the informal tests. For example, children in the informal tests added no attached planes, did not vary the shape of cuts, or add their own elements while all of the

children in the formal tests undertook these tasks. Third, closer work with single children in a controlled setting allowed for better observations of the children's actions and for interaction with the children to better understand their ideas and processes. Finally, the more complete pop-up building environment allowed the children to interact with more commercial pop-ups and instruction books, as well as providing access to more tools and materials.

There are two other interesting observations concerning the differences between the formal and informal testing. First, in the informal testing I observed that children encountered some difficulty in determining which direction the folds on 90° elements should be folded and there was no opportunity to see if this problem persisted over multiple pop-ups for each child. The formal testing proved that, in fact, it did not and children became quite proficient in folding the elements the right way. Daisy was the best at this, as she made quite a few abstract designs from 90° elements. Second, the “face problem”, the problem of how to place eyes on a design of a face when all elements must be placed on a fold that was seen in the informal testing did not occur in the formal testing. There, children making their first designs often wanted to be able to place elements other than on folds, but when they saw that they could not, they found ways to cope with the design problem. There may be many reasons for this, but I believe that among the most likely were the more sophisticated pop-up making environment and the presence of 180° elements. The environment provided other ways to make eyes, in particular the presence of googly eyes which the children loved to use. There were also fewer faces represented in designs, largely because with 180° elements more design possibilities presented themselves. For instance, Ursula started with a v-fold bunny and not a face as seen most often in the informal testing.

The rich pop-up making environment had its downsides as well. Most importantly, that environment with its readily available books, tools, and materials was far more complete than any in which most children will ever work. Most children will not have access to so many pop-up books or instruction books, as they are expensive and time-consuming to collect. In many cases, children would probably not have multiple colors of card stock or a good scoring tool available. Even a pen with no ink can be difficult to come by, as I discovered when I tried to

remove all the ink from one. This was, therefore, an experiment in what children could do in an exceptional environment, but there is comfort to be taken in the fact that children in the resource poor environment of the informal tests made striking pop-ups nonetheless.

Obviously, part of both environments was the researcher and some of the progress that the children made had to have come from interactions between the researcher and the children. While I tried to insulate myself from the process there were occasions in which I became a primary conduit for information. For instance, while I tried to only answer questions as the children made their pop-ups, there were times this was not sufficient. In particular, the 6 year-olds needed more guidance, and discussions about the pop-ups in commercial books and the ones they were making than could be provided by question and answer sessions. Two examples of my influence (as opposed to that of the software) stand out and can be easily identified as such. First, the 6 year-olds could not read and therefore could not have read the tool tips and help that provided names for the elements. Although they did not do as well as the older children in acquiring domain vocabulary, they did learn some. Ursula was able to identify v-folds in two instances and a tent in the *Farmyard* pop-up book. Richard correctly used the term “tent thing” but did not identify v-folds, probably because he had not used a v-fold at that point. They must have obtained that vocabulary from me and not the software. Second, while all of the children were familiar with the materials and most of the tools they had access to, none had ever used a scoring tool and their introduction to it came through my demonstrations.

This is, of course, a problem that occurs whenever one works with users on a complicated task, but it is arguably more common with children. The observer becomes part of the experiment. And in a sense, this is not entirely bad. Paul Johnson, who has been mentioned in Chapter 3 as an educator in the area of pop-ups and bookmaking says:

All in all, I have learnt to be practical and not idealistic in classroom situations like these. One must have the sensibility to recognize when intervention is necessary. The young can have a limited faculty of concentration and immersion in what they are doing. It may be better on occasions to make something for them than to run the risk of losing their enthusiasm because

a peculiar technique cannot be grasped. [58, p. x]

While in these tests I did not “make something for them”, I cannot discount the fact that I was involved directly with them and not simply observing them.

Creating the classification matrices of the pop-ups in Appendix G was a useful exercise for looking at the results of the children’s pop-up making. It suffers from two problems. First, it does not get at the artistic merits of the pop-ups and there is probably no way to quantify that aspect, unfortunately. Emilys *Tap-dancing Cow #47* is wonderfully charming and elegant, but saying that it was 2 v-folds, two attached planes and a flap cannot do it justice. Second, it does not provide the information needed to identify some common change among the children although it does show that each changed.

Another area that needs to be mentioned are the pre- and post- assessment tests. On the whole, the technique of asking the children to talk about the example pop-ups was extremely useful. These revealed each child’s vocabulary abilities and it was an excellent way to get them to talk about pop-ups. This can be difficult at times, as children do not want to vocalize their thoughts. Ursula, for example, was particularly quiet. For a few of the children I had pictures of their pop-ups and was able to ask them to talk about what they were thinking when they made them, which was sometimes useful. It would have been productive to have had all the pop-ups themselves so that they could talk about them as the effect of actually handling the pop-ups seems to promote verbalization. The technique of asking children to compare pop-ups was an idea that occurred to me during the formal testing. Therefore, it was not done at the start of the test sessions but only at the end. This might have been more useful if done at both times to see how the children’s abilities at this task changed over time. Finally, the email follow-up was very revealing, particularly their answers about which pop-ups were their favorites. Coming several months after the conclusion of the testing, the children were asked to reflect back on the work they had done which provided information not previously available.

As is the case with this type of work, some opportunities were missed such as obtaining

more information from the children as they worked, and some were muddled, as in the confounding of what my contributions were and the softwares were. In spite of this, the user testing was a valuable and productive exercise in seeing the children's pursuit of craft progress.

6.6 Summary

Informal testing of Popup Workshop was conducted in a classroom setting with 5th grade students, with middle school students in a summer program, and with adults. This informal testing helped to uncover issues with the software and to establish that testing would be best done over an extended period of time (at least 4 pop-ups in length), with a broader age range of children, in a richer standardized environment, and with a structured method of assessing changes in craft fluency.

The test environment included a range of tools and materials, Version 2.0 of Popup Workshop, and a variety of commercial pop-up books and instructional materials for reference and support. Each child worked individually with the researcher, and each session was videotaped. Photos of the pop-ups were taken and computer files produced by the users were saved. The users built pop-ups during one- to two-hour sessions, with 5-13 sessions per child.

Pre-testing activities consisted of two standard cognitive tests on spatial orientation and visualization as well as a discussion of each user's school and home interests and previous experience with pop-ups and other paper crafts. In addition, the researcher and each user looked at three commercial pop-up books, and one pop-up from each of these books was examined closely to allow the user to explain how it was made and how it worked. Examination of the books was also used during post-testing activities, along with discussions of the software and their experiences. In the last session, each user also compared two commercially-produced pop-ups dealing with the same subject. A final email follow-up questionnaire was sent several months after the sessions had concluded.

There were 5 users involved in the testing. The two youngest users, a boy and a girl, started at the age of 6. Three older girls were 11 or 12 when they began testing.

Craft knowledge was assessed by examining the use of element names. This was revealed by their discussion of the three pop-up example books. All users showed some knowledge of element names. The level of knowledge varied depending on the time a user had spent making pop-ups, their age, and the elements they had used.

The assessment of craft skill came from observations on tool and material use, and examination of the pop-ups created by users. It was hoped that the children would learn to modify elements and add elements or attached planes to their pop-ups. They all did so, although each child showed a different proficiency in and display of their acquisition of skills.

In assessing craft appreciation, primary data came from identifying the places where the users got their ideas. These ideas came from commercial pop-up books on occasion, and sometimes from each other. Users were also able to analyze the differences (although only at a high level) between the two pop-ups with the same subject. Appreciation takes time to develop, but they all appeared to have started.

Some general observations were made concerning the user's motivation in pop-up making and in particular other pop-ups they made during and after testing, on the way the children used the software, their opinions about their own pop-ups and what they did with the pop-ups after testing was over.

Finally, a more personal view was given regarding the differences between the informal and the formal user tests, the methods—what worked and what did not—and the influence of the researcher on the children and the results.

In Chapter 7, a more detailed look will be taken of two of the users, Emily and Peggy, who are twins and yet exhibited a great difference in their approach to and execution of their pop-ups.