



MULTIMEDIA RESEARCH

33 BROWNS LANE • BELLPORT, NY 11713 • (631) 286-8925

FORMATIVE EVALUATION OF *BUILDERS MATH* PROTOTYPE

by Barbara N. Flagg, Ed.D., Director, Multimedia Research
for *Cyberchase*, WNET Channel Thirteen
Research Report No. 07-016
November 30, 2007

BUILDERS MATH PROTOTYPE

As described by the Cyberchase team, the Builders Math “game presents missing building parts (as empty spaces) in a 3d perspective view, and asks players to measure the spaces so they can then cut out replacement parts to those exact dimensions in order to repair the buildings. The tools they are given for doing this include a particular 2d view of the building, a ruler for measuring point to point distances on the 2d view, and a cutting window in which materials can be measured, cut lines can be laid out, and cuts made to create 2d shapes. These shapes can then be dragged to the 3d view of the buildings and placed for repair. This game provides an integrated, goal-oriented problem that combines math skills in measurement, geometry, and visualization.”¹

EVALUATION PROCEDURE

During 40 minute sessions, four third grade girls and four third grade boys from a Long Island elementary school were observed individually while playing an early prototype of the Builders Math computer game. Students played the game on a 15” Macintosh iBook with an optical mouse, accessing the game from the hard drive using Firefox 2.0.0.9.

All students were familiar with the characters in *Cyberchase*, although several had not watched recently. Parents of all students reported that their children play computer games at home.

Students were introduced to the procedure as follows:

We are going to play a computer game on my laptop. The kids in your third grade are the first ones to use this game. I want to find out how to improve the game so that it’s easier to use. You can help me do that.

Hacker is the bad guy in Cyberchase. I want you to imagine that Hacker has been causing damage to Cyberspace buildings. In this story, Hacker has broken the window of this house [point to window in 3d rotating image]. See, my window is missing. Your job is to make a new window for the house.

¹ Email from Michael Templeton and Frances Nankin, 11/7/07.

The procedure focused on

- ability to read the text;
- interpretation of the terminology and suggestions for alternative terminology;
- transparency and usability of features; and
- comprehension of the four rounds of play.

Students enjoyed playing the game and were interested in playing the slightly harder rounds, despite limitations of the prototype. They became more facile with the interface as they played but did not necessarily improve in their comprehension of measuring shapes and transferring those measurements. Most students were ready to stop the program after working on the triangular windows; that challenge was frustrating. Problems observed and lessons learned are summarized below. **Suggestions for revisions and debugging are presented in red font.**

TEXT READABILITY

All but one user could easily read all of the text. **“Raw Materials” was difficult to read correctly and probably should be replaced with an easier phrase.**

TERMINOLOGY

Goal

All but one student understood the term “goal” as, for example, “solve problems;” “try to do something;” or “challenge.”

After playing one round, all but one respondent agreed that “challenge” was a better term than “goal.” The dissenter was the student who did not originally understand the term “goal.”

Raw Materials

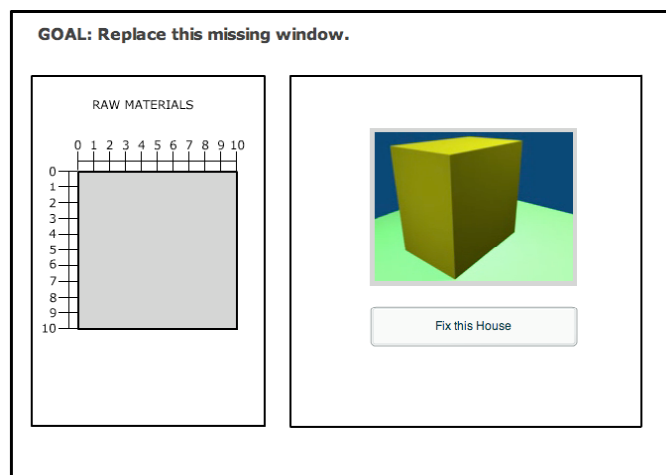
Six of the eight students were not familiar with the phrase, “raw materials.” Two students understood “raw materials” as “stuff.” After playing with the program, students suggested the following alternatives to “raw materials:” “materials;” “house materials;” “tools;” “raw shapes;” “stuff you can use;” or “wood.” **The suggested alternative of “window glass” was an acceptable substitution for “raw materials.” Consider also an action-based title like “Draw & Cut Here.”**

Fix This House

All students interpreted “fix this house” as “fix the window,” and **they suggested alternative wording like “fix the window” or “fix windows.”** “Play now” was not an acceptable substitute.

Rotate

All users understood that the term “rotate” meant “turn” the ruler or “turn around” the cut piece. **However, it might be clearer to use “rotate shape” in the ‘cut materials’ section rather than just “rotate.”**



FEATURES

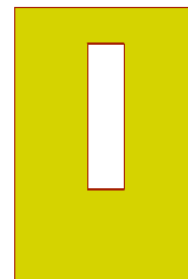
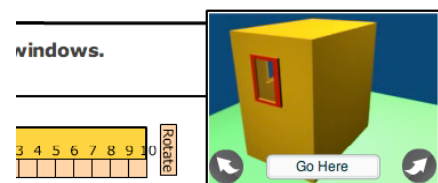
2d vs. 3d views

All students understood that the 2d and 3d views were related, but when asked to describe differences between the two images, five of eight respondents focused on color and size differences. Three students were aware of the dimensional distinction but did not verbalize the difference as number of dimensions: One noted that one image was “a cube” and the other was “flat;” another pointed out that we could “see the top in the top” image; and the third student said that one image was the “whole part” and the other image was the “square part.”

When asked directly what the difference is between 2d or two-dimensions and 3d or three-dimensions, two students could not answer but that did not appear to influence their game play. Six students had a reasonable interpretation:

- “2d is a “flat shape” and 3d is a “square shape;”
- “3d pops out more.”
- “3d pops out. 2d is just on a paper, a square or a circle.
- “3d comes back at you.”
- “3d looks real.”
- “3d shows the whole house. 2d doesn’t show the whole house.”

When asked to show the other side of the house, none of the students had difficulty seeing and using the turn buttons to rotate the 3d image. Everyone also understood what “you are here” means in the 3d image. One student referred to a similar feature on maps in her videogames.



2D View

Students liked having the 3d view in the program, but **in rotating the 3d view, they preferred that the image be less angled and more straight-on in its presentation.** This was particularly noted in Round 2 when users moved to the second window on the side (see image above). **Users also preferred that the window sizes in the 3d and 2d images match better in size and shape.** Again, the differences in the Round 2 second window were noted.

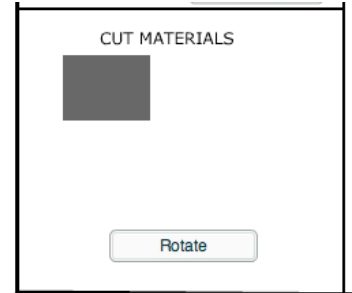
Half of the third graders understood that clicking on “go here” would change the 2d view; however, the evaluation procedure itself may have led to that conclusion. **Note that in the current prototype, when the ‘go here’ button is clicked on, it does not change to ‘you are here.’** See image above.

Also, two students commented that the window of the 3d house looks as if it has glass in it, when it is supposed to be empty of glass if Hacker has destroyed the window, as our setup story suggests (see window image to right).



Rotation button

No one spontaneously noticed the rotation button at the bottom of the cut materials section; however, once it was pointed out, everyone understood how to use the feature to rotate their shape on the house. **To attract more spontaneous attention, perhaps the button should be titled ‘Rotate Shape’ and placed higher, directly under the ‘cut materials’ title.**

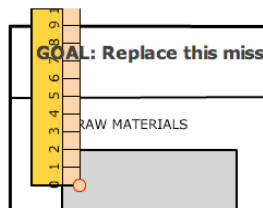


Ruler

Students had no difficulty understanding the use of the ruler for measurement, although several students tried first eye-balling lengths on the raw materials. They understood that the ruler had ‘units.’ Some referred to ‘inches;’ others did not specify unit type. All but one user manipulated the ruler so that measurement was always from zero up, not from 10 down or between numbers. All but one student did not want to write their measurements down, however, a few users would repeatedly measure the same side before making a point and line.

A good deal of interface frustration related to manipulation of the ruler. After seeing a demo of the ruler action (see demo movies), students typically did not have difficulty with the click and drag function of the ruler, **although occasionally clicking on the ruler while in the raw materials space yielded an errant ‘point’ rather than a ‘click and drag’ result.**

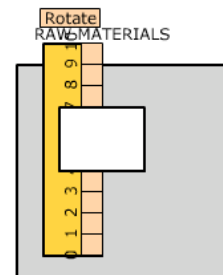
Students found the ruler’s rotation mechanism difficult to control, particularly when rotating in the raw materials space. **In the raw materials space, the cursor often flickered back and forth between a pencil and a hand, so the user was never certain whether a point would be made or the ruler would be dragged.** To compensate, some users moved the ruler out of the workspace in order to rotate it without the pencil cursor appearing.



Sometimes rotation in the workspace put the ruler out of sight to the left or top of the workspace (see image to left). However, students had little difficulty pulling the ruler back into the raw materials space. Rotation on the 2d display also put the ruler under the 3d image occasionally, but again students had little difficulty pulling the ruler back into the 2d display.

Students tended to rotate the ruler so that the tick-marks were next to the lines of the window being measured. **It might be helpful to include tick-marks on both sides of the ruler to minimize the need for rotation.** It was most difficult for users to rotate the ruler to a horizontal position, particularly when the ‘rotate’ word is on the left-hand side. (See RulerHorizMovemt.mov)

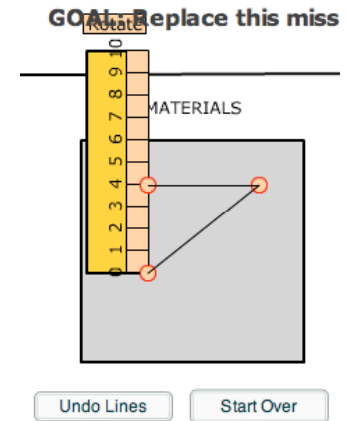
In the current prototype, the ruler can appear under a cut-out shape (see image to right). A real ruler would appear over the cut-out, not under. Also, it’s not clear that a line has been drawn when the points are at the edge of the ruler; the ruler edge and line are not visually distinct entities. **Perhaps red could be used for lines, as well as for points.**



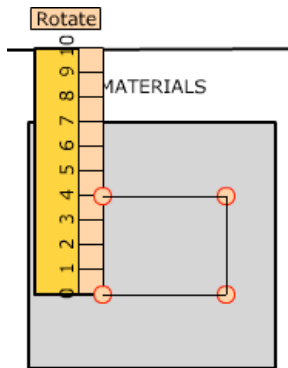
Pencil

Users could click on the raw material to make points and lines. The prototype quality of the program sometimes made the process frustrating because points could be made on top of the ruler; because points were difficult to place near the ruler as the cursor switched from pencil to hand; and because points were difficult to place near the edge of the material.

Half of the students spontaneously placed their points in a clockwise (or sometimes counterclockwise) direction, nicely fitting into the current prototype's logic. However, the other half of the sample, when making a rectangle, chose not to place points in a circular order and ended up having to start over (see image to right). Two students who received the most complete demo, which showed point sequencing, did not place their points clockwise or counterclockwise in their initial efforts. Since this is a programming issue rather than a player issue, we should provide some guidance through feedback or redesign. For example, when players click the first time on 'undo lines,' the program could provide an audio or Flash video feedback mechanism that hints at placing points in a clockwise (or circular) sequence. Alternatively, a redesign might have players place their three or four points on the raw materials and then click on a 'draw lines' button and a 'cut material' button.

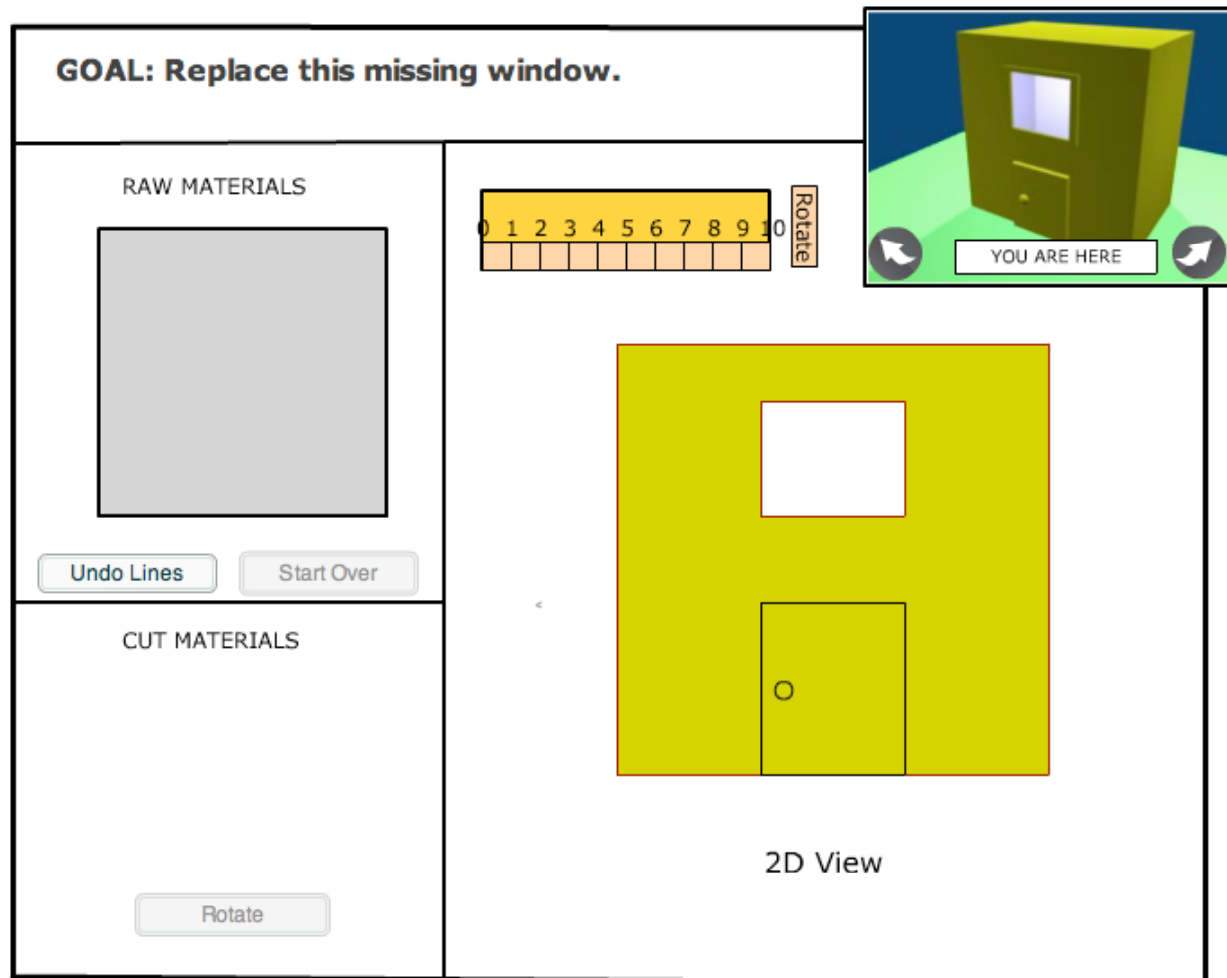


“Undo lines” and “start over” are helpful features, but an “undo” or “erase last point” feature would be most useful to eliminate mistakes and ease the frustration of having to reproduce correct lines.



All students chose to measure the final side of their shapes (see image to left), not noticing or perhaps not trusting the easy closure mechanism provided by the program – the red circle around the final point.

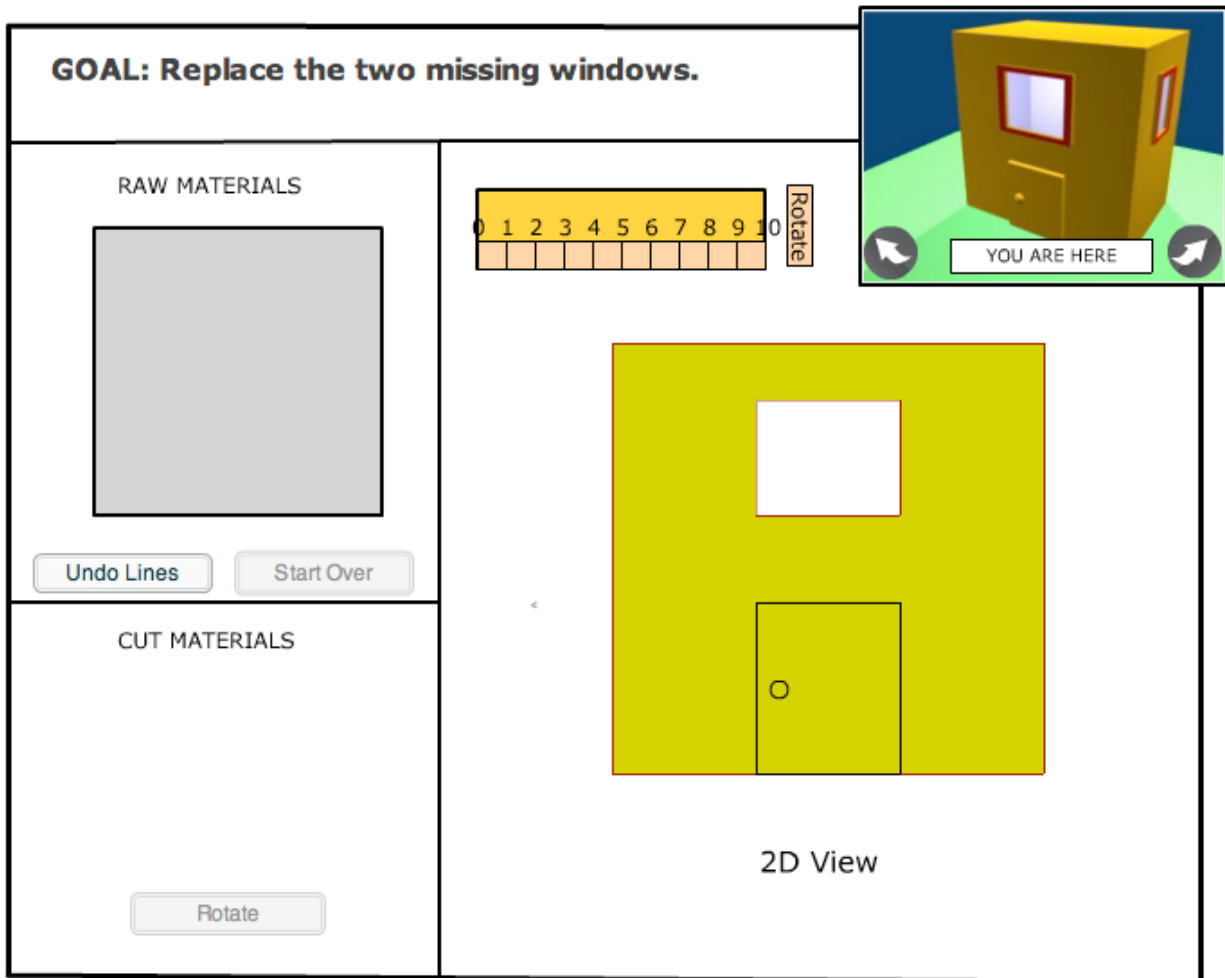
FOUR ROUNDS OF PLAY



Round 1: Create a single rectangle

This round gives the user a chance to familiarize themselves with the drawing and placement user interface. Because early subjects showed difficulty using the ruler and drawing features, later subjects were given a quick demo (see demo movies for different demo wording and length). **Providing a demo of the game action improved users' facility with the ruler and drawing features but did not influence their understanding of the task.**

Whether they received a demo or not, half of the students began on the raw materials by estimating the size of the window. Eventually all users measured the 2d window with the ruler and drew an appropriately sized rectangle. They noticed its appearance in the cut materials window. They dragged their shape onto the 2d view and were given appropriate feedback by the researcher. When the rectangle was too small, the player immediately noted the mistake; however, a rectangle that was slightly larger than the window was not always perceived as incorrect. **The program should include automatic feedback and reward.** All the students liked what they did in Round 1 and were interested in going on to a slightly harder game.

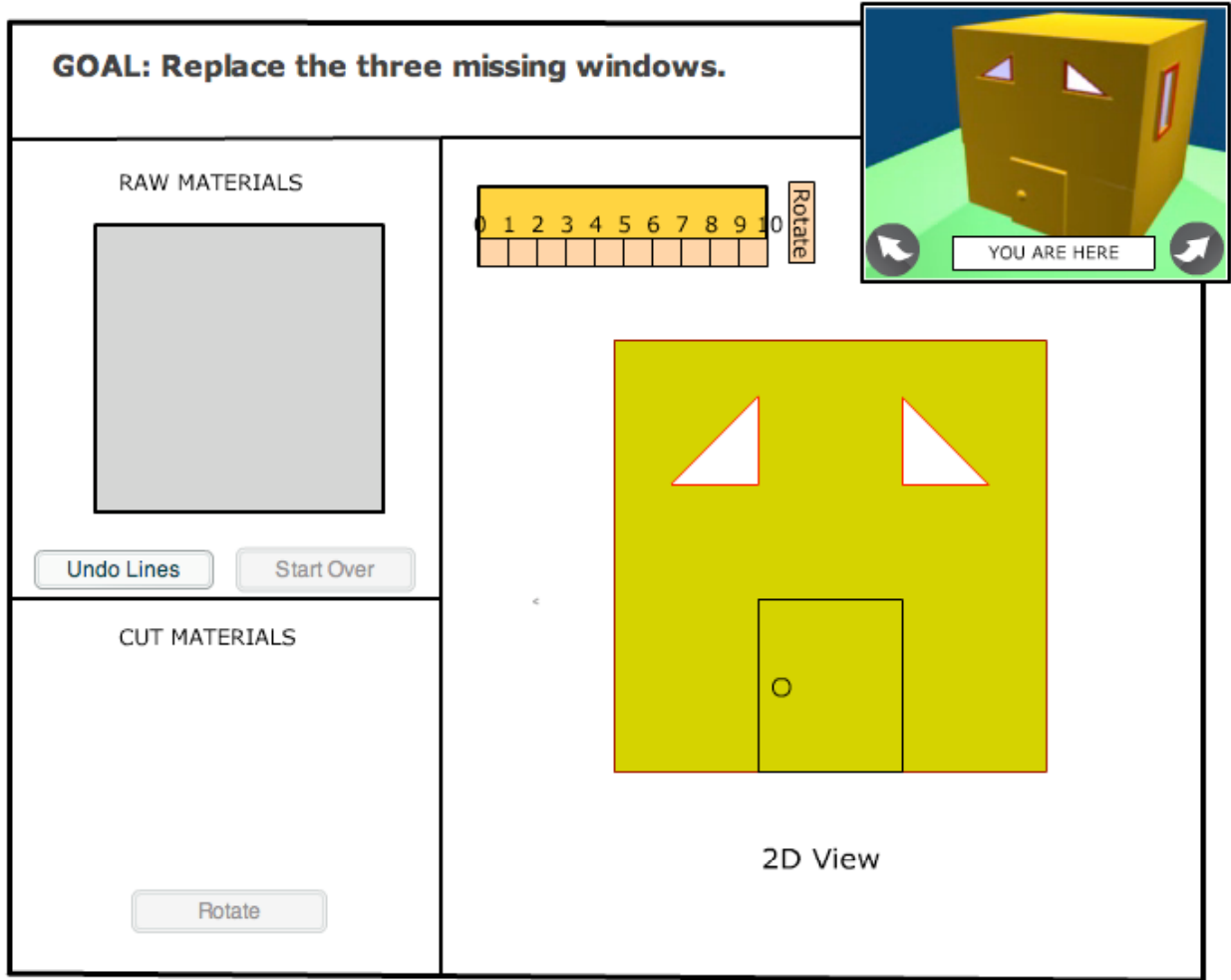


Round 2: Create two rectangles

This round of play gives the user a chance to familiarize themselves with the 2d/3d navigating mechanism, with a rectangular window on two walls of the house. The students had no difficulty figuring out how to turn the 3d image; however, clicking on “go here” to change to the second window in the 2d view was obvious to only half of the players. **It might make more sense to link a rotation in the 3D view to an automatic change in the 2D view, without the extra step of clicking on a ‘go here’ button.**

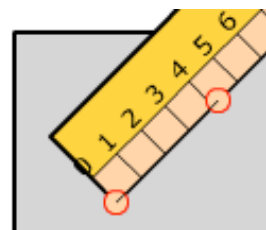
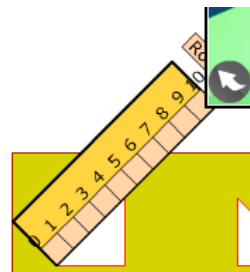
All students were better in Round 2 at measuring and cutting the first window. They had gained some facility with the interface and some understanding of measuring first and then cutting.

Only one student understood that cutting the first window used up raw materials and that the second window could not be cut in that same area: “I already cut that glass. I can’t go there.” Other students asked how to get rid of the first shape, used ‘start over,’ **or simply drew the second window on top of the first (which is a bug in the prototype).**

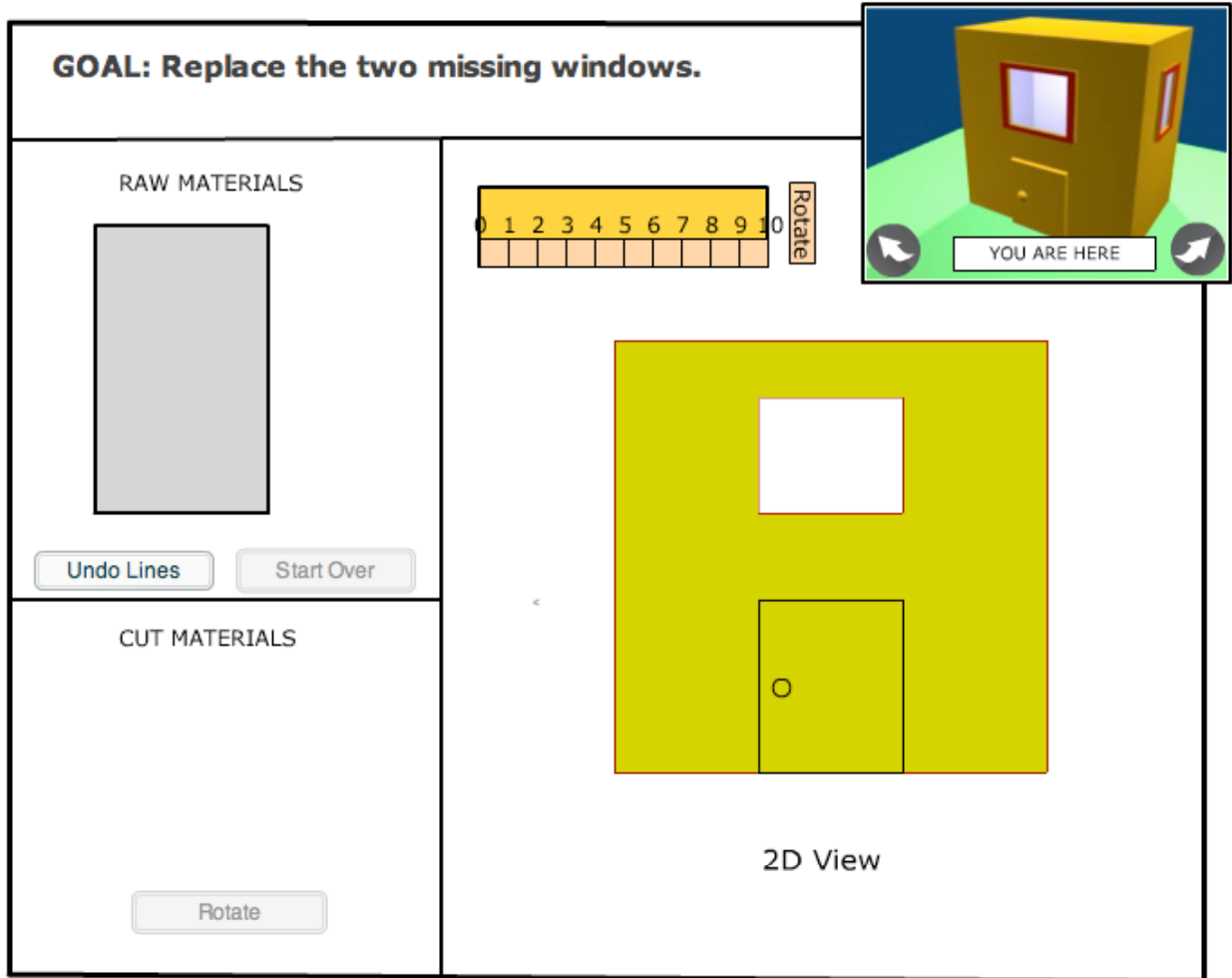


Round 3: Non-rectangular shapes along with multiple walls

This round of play expands the user’s experience to non-rectangular shapes and requires more thought about placement of shapes on the raw material. Due to time constraints, one of the eight students did not begin round 3. Six of the seven students who did begin this round started invariably by measuring the hypotenuse of the left triangle (see right-hand top image). They then dragged the ruler, holding the angle constant, to the raw materials (see right-hand bottom image). Placing points with the ruler at an angle is difficult because of the snap-to-grid mechanism of the program; the ruler tick isn’t always on a grid point.



Users had difficulties producing correct triangles for this round, **even when given a hint of “measure and draw the bottom and side first.”** The one student who spontaneously measured the bottom and side first, also then measured the angle and followed the doomed path of the other students. However, users persisted until trial and error produced a correct triangle. Of four students who completed Round 3, two did not want to play another round and two continued on.



Round 4: Multiple shapes

Round 4 includes rectangular shapes of previous rounds but the raw materials area is smaller, which forces the user to rotate one of the shapes. Two boys started this round and began in the same way. They both turned the 3d image to the side and opened the 2d view of the tall skinny window. Neither completed the task correctly, **cutting out their second window on top of the first (which is a bug in the prototype programming)**.

CONCLUSIONS

The Cyberchase team provided specific usability questions, which are answered below based on the data presented previously.

- *Do kids use the ruler on the 2d building to measure?* Whether they received a demo or not, half of the users did not use the ruler initially on the 2d building but instead estimated lengths on the raw material. Production of an incorrect shape and researcher feedback encouraged use of the ruler on the 2d building.
- *Do they use the ruler on the material to measure?* Yes, although eye-balling still came into play on occasion, particularly with the triangles.
- *Do they attempt to use it on the 3d view?* No; however, several subjects suggested that the windows on the two views should match better in shape and size.
- *Are they getting the relationship between the 3d view and the 2d view?* Third graders understand the relationship of the two views.
- *Is the 3d animation at the beginning of each round helpful? Confusing? Just eye candy?* Students liked the 3d animation and did not find it confusing, although several suggested that the 3d image present at less of an angle.
- *Did it raise expectations that the game would be played in 3d?* This was not asked directly but no one mentioned being disappointed by lack of 3-dimensionality in game play.
- *Was the way to change the 3d view clear?* Using the turn arrows to change the 3d view was transparent.
- *How about the way to switch the 2d view?* Using the 'go here' to switch the 2d view was less transparent but still user-friendly.
- *Did they notice that a new piece was created when they completed a polygon?* Yes, and users understood that they could click and drag the cut piece to the 2d view.

In addition to usability issues, two other evaluation questions were addressed:

- *Effectiveness of leveling the game by creating more 'repairs' in a given task, versus new tasks of greater shape complexity, including a sense of appropriate difficulty levels for our audience.* Players liked progressing to slightly more difficult tasks that included more repairs and different repairs. The tasks appeared to be at an appropriate level of difficulty for third graders. To encourage user perseverance, however, more support scaffolding may be needed as shape complexity (e.g., triangles) and difficulty (e.g., smaller material area) are increased. Also variability in house parts may increase interest.

- *Evidence of the cognitive impact of the problems kids are solving, including gender differences in approach, failure points and success rates.* Students learned the program interface over the 40-minute session but were not observed to learn new ways of solving the problems in the limited timeframe. There were no gender differences observed. The third graders demonstrated the most difficulty with triangles and also the limited raw material area; however, they were willing to persevere with a trial-and-error approach, which could be guided through hint mechanisms.