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**DESIGN AS AN AFFORDANCE FOR
COLLABORATIVE LEARNING: BEYOND THE
MEDIUM TO THE MESSAGE**

1. INTRODUCTION

Research in education has shown that learning about fractions can be difficult. Many curricula used in elementary schools incorporate the use of manipulatives to offer tangible, physical representations of math concepts. With manipulatives like pattern tiles, learners may discover relationships between shapes and how to fit them together in beautiful patterns. Our goal is to take advantage of this observation – to incorporate manipulatives into math and other areas of the curriculum such as art so that they promote understanding, foster creativity, and connect curricular areas. Constructionist (Papert, 1991) and Learning by Design (LBD) (Kolodner et. al., 1998, 2002) approaches both suggest taking a design approach to fostering engagement with and understanding of complex concepts (i.e., asking students to design patterns using manipulatives). Both suggest that a design approach affords learning not only concepts, but also design skills and skills involved in completing a project. However, project-based and design-based curricula can be difficult to implement, partly because it is easy to let construction consume too much time. With this foundation and caution in mind, we are designing a software environment and a set of challenges and activities that integrate learning math and art. Learners design patchwork quilt blocks and share and discuss them as a group to learn about fractions and simple art concepts. Before we can move forward with refining the collaborative activities, we need to create a design environment for learners that allows them to get at the learning *through* the process rather than in spite of it.

How can a manipulative-based design environment support children's design activities in such a way that it promotes understanding and fosters creativity, and that the artifacts created with it become things to think with and to collaborate around? What kind of support might help students notice mathematically interesting aspects of their designs? How can we guide

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exploration and discussion of the designed artifacts to enhance the overall experience? In this stage of the project, our quilt-design environment for students, called DigiQuilt, is allowing us to explore issues related to these questions. In our initial formative study, we explored the plausibility of the medium and integrated the software in the context of a greater learning environment. Based on our experiences in the classroom, we are adding tools to the software to help learners take advantage of the digital manipulative environment to learn specific concepts. We propose that these tools will help the students bridge the gap between their tacit knowledge of fractions and a deeper understanding by helping them notice mathematically interesting aspects of their designs. A design approach can lead to deep learning, but construction and design take time, and students may slip into simply trying to finish rather than trying to understand what they are doing (Blumenfeld et al., 1991). We are trying help students get a handle on the design medium to allow them to move into deeper content learning without the time barriers that tend to occur with physical construction of designed artifacts. In order to achieve that goal, we need to create an environment that affords making and manipulating designs without the construction and design process getting in the way. The tools and activities need to focus on making and strengthening connections between the concepts and the designs. This paper will begin by telling about the software and continue by describing current steps we are taking in the design based on results of a preliminary study (Lamberty and Kolodner, 2002).

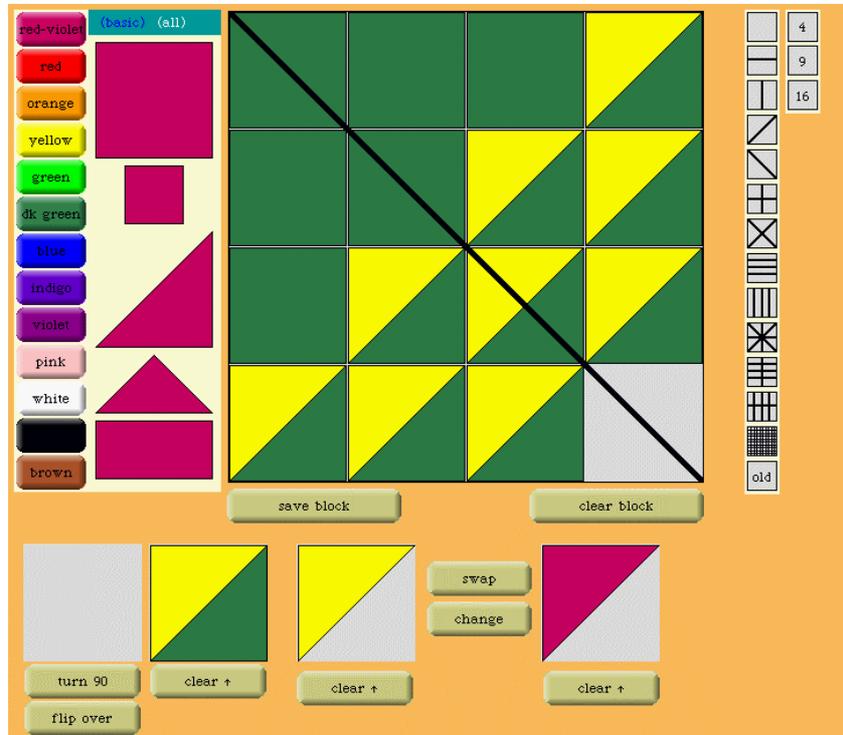


Figure 1. DigiQuilt screen layout. The “select-a-grid” tool has been used to impose the diagonal line on the design to aid in symmetry detection.

2. DIGIQUILT

2.1. Design and Foundations

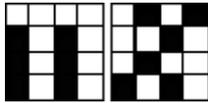
DigiQuilt (Figure 1) is a digital construction kit for designing quilt blocks. Users create quilt blocks by selecting colored shapes from a palette and placing them into a grid. Users can rotate shapes to be able to fit them together and place them to make patterns. The selection of shapes and their sizes is based on the ratios and shapes used in Froebel’s gifts (Froebel Web, 2001). For ease of making good-looking designs and talking about the math, all the shapes fit together easily and are sized as whole, half, or one-fourth of the granularity of the grids provided as a framework for the designs. DigiQuilt offers a workspace with a grid, buttons for saving images and clearing the grid, a shape palette with buttons to change their colors, a facility for rotating shapes, and a facility for saving grid patterns so that they can be easily repeated. DigiQuilt has the learner move the shapes to create the designs; much like a physical manipulative. We have focused on

supporting the learning of fractions and symmetry. By manipulating pieces, patches, blocks, and quilts, the learner can explore these mathematical concepts in an artistic way.

Constructionism suggests that engagement, and thus learning, is particularly efficacious when learners can design personally meaningful artifacts to share with an audience (Papert, 1991). The computer medium makes sharing, saving, and starting from previous designs easy. Eisenberg and Eisenberg (1998) note that using craft media for learning math motivates students because students participate in artistic, personal expression, and because of the possible longevity of the artifacts, which can often be displayed publicly. Learning By Design suggests some ways that we might orchestrate classroom activities to encourage deep learning of process and content through design projects (Kolodner et al. 1998, 2002, Kolodner & Nagel, 1999).

Our intention in integrating DigiQuilt into the classroom is thus to begin with introductory activities using physical manipulatives, much like the “messaging about” phase in LBD, and to present an overall challenge and then a series of smaller challenges. For each design challenge, the learners work in pairs or small groups using either DigiQuilt or physical manipulatives. After several design challenges are met, the small groups get together to share their designs and describe their solutions. Discussions guided by the teacher involve students actively presenting ideas and explaining different ways of understanding. DigiQuilt and its activities supplement existing fractions curricula rather than replacing them.

2.2 Proposed Changes Based on the Results of the Initial Study

 Our initial study involved 16 third grade students (ages 8-9) at a suburban elementary school. We began with two pretests and some introductory activities and then assigned students to work with either paper or computer-based manipulatives to complete several mini-challenges. On the pretests, an interesting phenomenon stood out. When asked to compare the amount of black in two quilt blocks (like those shown to the right) using words, 14 of the 16 chose the correct words. On a similar problem with symbols instead of words, only 10 answered correctly, and when asked to place the correct symbol (<, >, =) between $1/2$ and $2/4$, only two answered correctly. This suggests that many students are not making the connection between the concrete and abstract representations of the fractions and symbols: here was an opportunity to connect the manipulatives to solving a problem. To help them see another way to look at the problems, we moved the shapes (grouping them as shown to the left) and described what we were doing. The kids looked confused. After a couple of times moving the shapes one student said, “Ooooooh. I get it. It’s the same *amount* so it’s the same *fraction!*” Her tacit knowledge about the equality of 

the area covered by the squares was thus connected to the idea that the two different formal representations were equal. By leading the other students through her thought process, she shared that connection.

Usually, by working in groups, students were able to complete mini-challenges without asking for much guidance (if any). Sometimes, though, the students needed help. When students were stuck, usually it was the difficult fractions in the challenge that confused them. One scaffold that seemed to help learners understand the fractions was helping them look at the workspace in a different way. For example, when faced with the challenge, “Make a quilt block that is $\frac{1}{2}$ yellow, $\frac{2}{8}$ red, and $\frac{1}{4}$ blue,” it became clear that students were not thinking about breaking the block up into three pieces that would add up to one whole and that they did not understand that $\frac{2}{8}$ and $\frac{1}{4}$ were the same. By emphasizing certain lines on the paper grid, we were able to help them focus on different ways of breaking the grid into various sized pieces and focus on the part-whole relationship.

Based on experiences like this one, we are adding a “select-a-grid” tool (figure 1, on the right) that will allow students to choose different grids to overlay on their designs. The grids divide the design in different ways to allow the students to see several of the many ways the designs can be broken up. Our thought is that if it is easy to switch between seeing the same design broken in half, fourths, or other fractions, it will be easier to understand how those fractions relate to each other and can be used to express the same number or amount.

When symmetry was the focus of the challenge, different difficulties arose. Some students had difficulty visualizing folding their designs to check for symmetry. Stepping through each pair of patches to see if they matched up could be confusing. There was no tool specifically designed for that purpose. The new “select-a-grid” tool may also be helpful to students exploring symmetry since several of the grids also divide the designs along possible lines of symmetry. Another possible tool would guide students through the process of checking pairs to see if they match properly. Finding the pairs of patches across a diagonal line of symmetry was especially difficult for students.

Students felt strong personal connections to their designs, but we think if the quilt blocks looked even more realistic they would be more motivated. In addition to adding a facility to add digital “fabrics” or textures, one tool that we added should reduce the time and effort involved with changing quilt blocks’ color schemes. Students wanting to switch all blocks of a certain shape and color to another color can now do so at the touch of a button. This tool will enable students to make quick changes to their designs to explore various combinations of colors and patterns. The “color-change” tool promotes exploration by making it easy and fast to make changes.

3. DISCUSSION

Our initial hypothesis was that patchwork quilt designs would be a plausible medium to enable students to learn simple math and art concepts, and that digital manipulatives would offer some affordances that physical manipulatives lack (Lamberty & Kolodner, 2002). A formative study showed that students were able to successfully create solutions to the easier challenges, but that support was needed for more difficult challenges. Also, while formal representations of fractions can be difficult to understand, using visual or concrete representations, many students were able to compare fractions (as illustrated in the example). It is our hope that a properly supported design approach will help bridge the gap between this tacit knowledge and a deep understanding. We want learners to move beyond construction to challenge themselves and each other to understand the concepts.

In general, getting started on the computer seemed slightly less intuitive than getting started with the physical manipulatives, which could be manipulated and used right away in some capacity. Adding tools and other supports for learning *through* the design process without adding *time* to the process is likely to get the students to try to understand the concepts they are exploring. Tools like the copying tool and color-change tool simplify the construction process by making it faster to make and change designs. Tools like the select-a-grid tool support exploration of different ways of representing fractions by making it easy to break up the designs in a variety of ways. In our initial study, construction took up more time than discussion, and the two processes tended to be separate. We intend to bring the focus back to the math more often in our next study. By supporting the design process in several new ways, we think DigiQuilt will help us achieve this goal.

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