Geometris: Designing Collaborative Mathematical Interactions For Children

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Abstract
We present Geometris, a collaborative embodied geometry game for 6- to 11-year-old children. As shapes are projected onto the floor, players recreate those shapes on a 6x6 feet interactive mat. At the end of each level, a geometric pattern - the result of overlaying all created shapes - is displayed. Two dimensions of user interaction—mobility and division of labor—emerged during pilot gameplay sessions. We hypothesize that these interactions offer resources for children to learn geometry concepts as well as collaboration skills.

Author Keywords
Educational game; embodied learning; collaboration.

ACM Classification Keywords
H.5.2. User interfaces: interaction styles; K.3.1. Computer Uses in Education

Introduction
Mathematics is often portrayed as an abstract, solitary, and formulaic field. Geometris, an embodied and collaborative game, creates an environment in which young math learners can experience geometry as tangible and collaborative. The game enables physical movement as a means for thinking and talking about shapes. Its design requires players to work together to
fulfill the provided challenges. Aligned with the idea of experiencing math in a different way, the score of the game features aesthetically pleasing geometric compositions rather than numerical scores often associated with high-stakes assessment.

The Geometris environment is composed of a 6x6 ft interactive mat and a 4x6 ft projection area [Fig. 1]. Two dimensional shapes are projected onto the floor near the mat, descending from the top of the projection area toward the red line at the bottom. Players work in groups to create the shapes on the mat by pressing only the pressure-sensitive pads that correspond to the vertices of the projected shape. To accomplish this task, children need to work together and coordinate their bodies. Each game level consists of 8 shapes and is scored by overlaying all successfully created shapes [Fig. 2]. Real-time feedback is provided both through an LED on each pad and in the projected image.

Related Work

Geometry is a fundamental pillar of mathematics [7]. The Common Core State Standards in mathematics for kindergarten to fifth grade include skills such as: comparing shapes by number of sides and corners, distinguishing identifying features (e.g. number of corners) from non-identifying features (e.g. size), and recognizing symmetry [6]. Spatial reasoning also poses particular challenges for older students as they study translations, rotations, and reflections of transformational geometry [2].

To address these challenges, some researchers emphasize the role of physical movement, arguing for embodied learning as an essential educational resource [1], with some math educators claiming that mathematical reasoning is rooted in bodily experiences [3].

Collaboration has also been identified as a critical skill for children. Specifically, working in dyads or small peer groups has been shown to facilitate children’s learning and development [8]. The benefits of collaborative learning extend to mathematics, where research indicates that pair and small group work supports children in reasoning tasks [4]. We ground Geometris in these research findings, and through this game we aim to foster interactions that aid children to a) experience geometry in a new way, and b) develop collaboration skills.

Geometris interactions were inspired in part by existing games. We sought to recreate a sense of humorous frenzy in coordinating multiple players within a shared space as in Twister®. Geometris’s augmented mat is not unlike the traditional DanceDanceRevolution interface. In using elements of well-known games, we built on familiar game mechanics and user interfaces and add educational content to the experience.

Interaction Dimensions & Play Scenarios

We borrow Salen and Zimmerman schemas of rules and play when characterizing game design [5]. Rules define the essential structures of the game, and play captures the participants’ experiences and social interactions with the game. Geometris has two rules: 1) players must create each shape before it reaches the red line at the bottom of the projection, and 2) for a shape to be validated, players must activate only the pads corresponding to the vertices of the shape. Nevertheless, the play - the way users interact with the...
game - can be modulated by emphasizing different dimensions of the game.

*Geometris* play can be modulated along two dimensions: division of labor and mobility. By division of labor (DoL), we mean the distribution of resources and responsibilities among players. By mobility, we refer to whether or not players move around the mat.

In balanced DoL play, all children view the projection and share equal responsibility for creating the shapes on the mat. By contrast, unbalanced DoL play requires two distinct roles. “Guides” can see the prompted shapes but are instructed not to use the mat. Remaining players can access the mat but cannot see the prompted shapes and thus rely on the guide’s instructions to construct each shape.

Balanced DoL play gives all players access to the same resources and responsibilities. In pilot tests, players negotiated those resources and responsibilities with different results. Some pairs spoke freely, sharing their thinking and directing each other; other pairs spoke little and gave directions through gestures. Consequently, this kind of play may be influenced by social comfort and power dynamics.

Unbalanced DoL play relies on verbal communication and is conducive to surfacing language about shapes and space. For example, geometric shape names (triangles, trapezoids, etc.) could emerge as a tool that streamlines communication and enhances performance, motivating players to learn these terms. However, resources are not equally distributed among players. If players do not rotate through roles, they may not have access to the same learning resources.

Play also varies along the dimension of mobility. In mobile play, players move freely around the mat, activating any pads they deem necessary. Children playing an immobile version of the game may not move around and instead are responsible for the 1-3 pads in their immediate vicinity. A sitting position facilitates immobile play, as it hinders gross body movement.

Mobile play facilitates a full-body experience of the shapes as players move, reorient, and stretch their bodies to create shapes. However, in this kind of play, children can occupy more than their “fair share” of the mat, even completing shapes without their peers’ contribution. Again, collaboration is contingent on players’ social relations and power dynamics.

While immobile play reduces the embodied experience of each shape, it distributes shape-creation over all players, prompting communication among them. It also presents an additional spatial reasoning task during a balanced DoL play scenario. When players are oriented differently relative to the projection, some must mentally rotate the projected shape before deciding whether or not to activate their pad [Fig 3, quad. II].

Figure 3 illustrates the plane in which these two dimensions coexist. Play scenarios can be located in one of these four quadrants. For example, in QI (unbalanced DoL play, immobile play) the projection area is located where only the guide can see it. Remaining players sit on the floor around the mat and follow the guide’s instructions. In contrast, in QIII (balanced DoL play, mobile play), all players see the projection and move freely around the mat.
Conclusions and Future Directions

We are currently planning user studies with children to evaluate the play scenarios suggested above and to study the geometry and collaboration skills children develop through gameplay. We also plan to address needs raised through pilot testing, namely using non-skid material for the mat and allowing players to control the shapes' speed, perhaps with a knob.

We created *Geometris* to provide children with an experience of geometry as tangible, intimate, and collaborative. Preliminary work surfaced division of labor and mobility as central dimensions of gameplay.

We seek to continue adapting *Geometris* to suit the physical, social, and developmental needs of young mathematics learners.

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References