Merging Physical Manipulatives and Digital Interface in Educational Software

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Abstract: In this paper we describe how elementary school students used physical manipulatives in conjunction with the digital interface of educational software for geometry. The blending of physical manipulatives and digital interface may help them to overcome the limits of the representation and interaction modalities of the digital interface.

Introduction

Our study used SuperTangrams (Sedighian & Westrom 1997), a program developed by the EGEMS group at the University of British Columbia. We introduced manipulatives that students could use while playing with the software. The idea was to use manipulatives in conjunction with the software in order to overcome the representational problems of the interface. Manipulatives allow the students to experience what they are doing on the screen in the real world.

SuperTangrams. SuperTangrams is a computer-based learning environment for two-dimensional transformational geometry. Learning of this mathematical domain is situated in the context of the traditional tangram puzzles game activity. The player is challenged to put together several geometric shapes to fill a given outline. To move the shapes on the screen the student selects and applies to them one of three transformations: translation, rotation, and reflection.

Subjects and Settings. The study involved approximately 180 fifth grade students at a College Station, Texas, elementary school. The task of each student was to play with SuperTangrams to solve the tangram puzzles. The student was free to use the tools that we placed on the side of his computer. Data collection techniques included class observations, video-recordings, scratch paper used, pre-tests and post-tests, questionnaires and log files of computer sessions.

Use of Physical Manipulatives

First set of manipulatives

During a first study session (two weeks), we provided the students with the following manipulatives:
1) a set of tangram plastic shapes, 2) a reflection mirror, 3) a colored grid board with a rotating stick.
The board had two different drawings on it: a line for reflection and a circle divided in 16 sectors of equal size. This is consistent with the software that allows the minimal angle to be 1/16th of a circle. A stick is connected to a hub at the center of the circle and can rotate 360°. The idea was that the students would place a shape on the circle and then rotate it by pushing against it with the stick. We intended for them to use the reflection mirror with the line drawn on the grid board to find the reflection line.

Rotation. One common use of the shapes was to put them on the screen and animate them. A video recording shows a girl using them for rotation. She started superimposing one plastic shape on the digital shape on the screen, and then she moved the shape along the arc of rotation trying to move and rotate it at the same time. In this operation she paid attention to the position of the shape on the screen, but not to the orientation, or angle of rotation. The students who used the grid positioned the plastic shape on the circular drawing, trying to position the shape in the same orientation as the one on the screen. Then they would push the shape with the stick until the shape could reach the orientation of the target. They would count the number of sectors the stick moved and
move the digital handle accordingly. Some students felt comfortable with the board, while some others preferred to bring the shapes directly to the screen.

Reflection. Students did not use the mirror on the grid board with the plastic shapes as we had expected. Instead, they placed the mirror directly on the screen and looked for the reflected image of the digital shape. The first operation involved was to position the mirror until they could see the reflected image superimposed on the target. Once the position was found, they had to play with the digital handles to position the reflection line along the position found for the mirror.

New Manipulatives
The use the students made of the manipulatives surprised us, since they preferred to use them on the screen, merging the physical operations with the digital ones. Thus, for the second session, with a second group of students, we modified the manipulatives to make it easier for the students to use them on the screen. We eliminated the grid board and built a rotation tool consisting of two popsicle sticks joined together at one end in such a way that they could rotate, and placed some sticky paste on the other ends. The popsicle stick had more success than the grid. The students would stick the chosen shape at the end of one stick, and position the two overlying sticks directly on the digital radius of rotation, with the plastic shape matching the digital shape. Then they would rotate the stick holding the shape and keep the empty stick in the initial position. When the plastic shape reached the target, the opening of the two popsicle sticks represented the sought after angle. In this case they could hold the right "angle" in their hand. Finally, they would recreate the digital angle playing with handles, holding the physical one as a model.

Student reactions
The second set of tools had more success than the first. It was more natural for the children to bring the tools to the screen, and they could physically experiment with the transformations. In the questionnaires we asked children if it was good to have manipulatives, and if they helped them learn. Here are some of the answers:

"They helped because they were 3D;" "they helped you to learn the movement;" "all tools because they helped you think ahead;" "you need some reference to look at;" "because it is important to have stuff you can work with in your hand;" "it helps understand."

Conclusions And Future Work
Software running on a computer is something abstract: when the student drags a handle with the mouse something happens on the screen. In educational software for geometry it is important that the student learns to relate what happens on the screen to the real word. Our preliminary findings indicate that physical manipulatives can be a valuable addition to educational software. We noticed how the use of manipulatives helped students overcome limits of the representation and of the types of interaction allowed by the interface. For example, additional information on the screen whose purpose was to help the students, such as additional lines, actually confused them, causing them to miss important concepts. Using a physical representation of those concepts, such as an angle between two popsicle sticks joined together, helped them to focus on the main aspects of the transformation without being lost in representation details. During our study we collected log files and data relative to pre-test and post-test. The statistical analysis of this data will determine the effect on learning of the different tools.

References

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