OUT OF THE BOX: A CLASSROOM EXPERIENCE WITH MANIPULATIVES AND TECHNOLOGY

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This poster describes a classroom experience designed around the use of technology and manipulatives for middle school geometry to explore and understand the abstract manifestations of the concrete world. It is based on the belief that students build understandings through iterating, learning and doing. They need scaffolding to build upon prior knowledge, to build new understandings and to build physical objects representative of the abstract concepts that they learn. Using our project, students will be able to explore geometric relationships, formalize them and build empirical models.

LEARNING PROBLEM

> "Only about 50% of US students ever take high-school geometry. Even within geometry, we often see more emphasis on verbal than on visually based reasoning." - E Paul Goldenberg, Distinguished Scholar at Center for Mathematics Education, EDC.

Geometry in middle school has been identified as a crucial milestone in the K-12 mathematics trajectory. Goldenberg when asked, what was the one thing he would want middle students to be prepared with responded that it was the relationship between 2D and 3D. Students do not get nearly enough exposure to hands-on learning opportunities given the constraints of the regular classroom. The Mathematics Standards Study Group emphasizes the importance of geometry in early grades. Our goal is to provide a tool to assist teachers to incorporate hands-on activities in busy classrooms.

CURRICULUM AND TECHNOLOGY

> "...the child who is familiar with folding and unfolding paper shapes through his work at school is two or three years in advance of children who lack this experience." - Piaget

Our project was based on the idea that a clear understanding of the relationship between 2D and 3D geometry has proven to be an invaluable aid for future math learning. Currently, students have little exposure to hands-on methods for understanding these relationships. Textbooks are 2D representations of 3D concepts. Equations are seen as having little or no relevance to real world applications. Also with existing dynamic geometry software, we found that there was no way to connect the virtual exploration with a hands-on experience.

It is our aim to provide a tool which helps make these connections. Our tool consists of an applet which is a proof of concept for a software intervention to augment and enrich the students' use of the manipulatives. The related lesson plan provides the details of the hands-on activity that make the virtual exploration more concrete. It uses transitional objects to help classroom conversations and collaboration. It also leverages research that indicates students are more likely to be attached to physical objects than images on a screen.

We envision the design of an entire geometry curriculum taught through the building of a collaborative artifact. Our prototype of this vision is the generation of a 3D puzzle of the Trans

America building. The software helps the students design 2D folding maps of the various 3D pieces of the puzzle. The possible range of topics that can be taught using this activity are scale, angles, volume, surface area, trigonometry.

ASSESSMENT

We based our assessment on the premise that the use of manipulatives in geometry classrooms makes a positive difference. We observed classrooms in different settings where our project was used. This informed us about the beneficial role of manipulatives in conjunction with software. It also helped us to identify the appropriate age group for this kind of interaction. We field tested this project in three grade levels – sixth, seventh and a senior (12^{th}) calculus class.

3 Classrooms

The similarities and differences between the three classrooms that we visited with our teaching intervention are interesting enough to warrant a mention here. All three were public school classrooms from the Bay Area in California. All of them had around 30 students. In all three classrooms, the students were trained in how to do small-group work. They were aware of roles and responsibilities when engaged in collaborative group work.

The demographics of the classrooms were very different. The eighth grade classroom was located in a school (JLS) mainly populated by the affluent middle-class. Most parents are professionals and the ethnic origins of the students are Caucasian, Asian and Asian-Indian. The sixth (HRC) and the senior(12^{th}) (SLZ) grade classroom were in schools located in lower-middle class areas with a predominantly Hispanic population. The JLS school appears to have better facilities than SLZ and HRC. The engaged behaviour of the students and prior understanding of fractions was in keeping with the appearance of the school. SLZ and HRC on the other hand were similarly economically depressed and but the level of engagement in both of them was very different.

Calculus is an optional Math class in California. It is rare to find a class of 30 seniors taking Calculus; especially in a school like SLZ. The students were very focussed, very glad to be learning and the social conversations centered as much around college prep exams as around the latest music.

Our mode of conducting the lesson was also very different in the 3 classrooms. In HRC, we were four of us and we taught the lesson over a 3 class periods, with the teacher as a non-participant observer. In the senior class, the teacher and we developed the lesson plan in collaboration. He conducted the lesson while we assisted in the technology aspect and were active observers. In JLS, the teacher took our lesson plan, modified it to suit her classroom and conducted the lesson while we were non-participant observers.

Given the differences in grade levels of the three classrooms and the environment, it was important to develop a coherent assessment rubric.

How we looked at what we saw….

The number of components of our intervention posed a challenge when it came to evaluating the influence of the manipulatives in conjunction with software. Our curriculum and technology did not lend itself well to Experimental Design consisting of control and experimental groups. We settled on a proof of existence evaluation. We designed a classroom observation protocol to capture the different ways in which we thought it helped the classroom interactions.

Category	Frequency
Empirical Validation	
Keeps going back to the box	
* If wrong, find mistake	
* If correct, verify the answer	
Tangible object for group collaboration	
Moves the conversation along	
Helps them to build on each other's ideas	
Enables shared understanding	
Makes the implicit explicit	
Scaffolds prediction and formalization	
Allows for hypothesis testing through building prototypes	
Takes the equation from abstract to concrete	

Table 1: Classroom Observation Protocol.

WHAT WE SAW AND WHAT DOES IT MEAN….

The observation protocol helped us to identify the salient aspects of the classroom interaction. We decided to categorize our observations in the following categories. We also attach our field test writeups here.

- **Visualization** : Build mental models by watching 2D transform to 3D
- **Empirical validation** : Makes the implicit explicit
- **Kinesthetic input** : Provides active stimulation for thought and action
- **Tangible object for group collaboration** : Gets everyone on the same page
- **Moves the conversation better** : Encourages discussion around math
- **Scaffolds formalization** : Provides knowledge to make an educated guess
- **Memory tool** : Lets you walk away with an artifact

12^{th} grade field test

The class consisted of 28 students arranged into groups of fours. The students are accustomed to working in groups and do so effectively and without much teacher involvement. We chose to have Mr.D., conduct the class, to allow us a chance to observe closely the students conversations. The problem that was posed was optimization. They needed to figure our how to build a box from a single 9x9 sheet of paper that would give the biggest volume. In addition to actually building the box, we were looking for the analytical solution, a t-table of values, and a graph of the variation plot points from the t-table, including the point of inflection. The students were challenged to then explain how these values relate to one other and also back to the folded paper boxes.

Unintentionally, due to lack of computers, we had somewhat of a control as only two of the groups had access to our Java applet. We noticed that of the two groups with the laptops, one started off guessing the biggest volume values, using the software, while the other attempted to get the equation before even touching the software. The group that guessed the initial values used the software to give them a guestimate of the value. The group that chose not to use the software initially, wanted the ability to plug in a number as a mode of checking it, after they had solved the equation. Our software did not allow the manual entering of values, but because of their recommendation will in the next product iteration.

The most interesting instance we observed in this classroom was when a group, who were not using our applet, after solving the problem, realized that they were wrong by actually building the box. Seeing this led us to believe that it (the value of handheld manipulatives) was worth investigating.

6^{th} grade field test

The lesson fit in well with their curriculum, however some of the students struggled in some places we had not foreseen. Understanding how to measure in inches versus centimeters, multiplying fractions and graphing were three areas that could be addressed in the activity. We could include additional lesson plans that would remind the students of how to multiply fractions, let them practice measuring and introduce them to graphing. Scaffolding the activity, specifically the graphing activity would allow them to absorb the material at a more reasonable pace. In doing so, we would be redesigning the lesson to consider a general classroom rather than the specific conditions of Nancy's class.

Our assessments of the student's learning consisted of group discussions as well as an individual free write at the end of the day. The worksheets also included space to document their thoughts, insights and approaches. Some students took the free write more seriously than others and as a result we received a broad range of feedback. This may have been due to the little emphasis put on the free write. It came at the end and needed more time; the students needed more time to think about their process.

NEXT STEPS…

The important takeaway lies in the possibilities that this opens up for curriculum based on manipulatives in higher than primary grades. We envisage an entire geometry curriculum based on the construction of a collaborative artifact. We worked on a pilot of this idea by constructing a TransAmerica Pyramid building made up of 3D blocks shaped like puzzle pieces. The applet is now available as a Math Toll on the math forum website http://mathforum.org/library/view/66581.html. The Math Forum is an online community for math teachers that has been instrumental in combating pedagogical isolation for many teachers – especially those in rural areas.

To learn more about the project process; you can visit http://ldt.stanford.edu/~outofthebox. To learn more about the LDT program at Stanford, visit http://ldt.stanford.edu.

Additional information

Please contact Vishakha Parvate at vparvate@keypress.com for the latest version of the applet and curriculum ideas and permission to use this in your classroom.

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