



**Fort Worth Museum of Science and History**  
[www.fortworthmuseum.org](http://www.fortworthmuseum.org)

# Fort Worth Museum of Science and History

## Extraordinary Learning Environments for Mathematics

The Fort Worth Museum of Science and History, in Fort Worth, Texas, is familiar with change and is following new directions. Started as a childrens' museum in the 1940s, it had become a science and history museum by 1960. In the mid 1990s, Fort Worth determined that it needed to think differently about its role in the community. According to Don Otto, president of the museum,

*It was time to stand back and take the long view—for what will be in the next 50 years. Fort Worth has a collection, but is not a research institution. Where we had considered ourselves a teaching institution for half a century, we saw a strategic advantage in approaching our next 50 years as a learning organization.*

Staff took a hard look at their business. They brought in stakeholders from the community and thought about their values. They looked at the nature and quality of existing exhibits, and decided to try thinking in new directions. Ultimately, they chose a new guiding principle: Focus on learning, and you can change the world.

Fort Worth's goal is to create "extraordinary learning environments." The strategy is to establish successful partnerships and take small risks as investments for future teacher and family involvement. One tactic has been to invest in staff professional development and to encourage knowledge about inquiry, understanding about leadership, and skills in facilitating adult learning.

A big first step involved increasing Fort Worth's capacity to do inquiry. Staff members attended ASTC's NSF-funded Inquiry Institute for Teacher Educators and visited other science centers with inquiry discovery labs. Partnering with the Exploratorium has helped to cement this approach. Fort Worth also acquired a model for leadership development from the National Academy for Science Education Leadership, and staff made significant strides in building relationships with key stakeholders in the science education reform effort in Texas.

Fort Worth enhanced its facilities by creating a new Center for Science Learning, where teachers can meet and parents can gather. It created the Hands-On Science Learning Laboratory as a place for inquiry investigations. And it is in the midst of a fund-raising campaign to remodel and expand the museum itself.

## Commitment to Building Relationships

The decision to focus on learning has had a powerful influence on programming and fund-raising at Fort Worth. The key has been to create relationships and build long-term partnerships with schools and to connect with other organizations trying to engage in systemic change in education. This philosophical stance brought Fort Worth into alignment with the Texas State Systemic Initiative (SSI)<sup>15</sup> and helped initiate the statewide Informal Science Network, in which Fort Worth has a key leadership role.

These connections prompted the Texas Science Teachers Association to establish a position on the board for informal learning institutions. Through Fort Worth's partnerships with universities and school districts, the museum participated in family learning events in mathematics and science, and staff member Colleen Blair began exploring the potential of working in preservice education.

The connections, collaborations, and relationships continue to build, with Fort Worth bringing in people from across the country to help them think about new directions. The strategy is to invest in audience development over the long term. Sometimes new audiences—like the preservice teacher education programs described below—are invited in at no charge. Participants are given passes for individual return visits. Ultimately, these visitors develop a new appreciation for what the museum offers and sustain the relationship through memberships and paid admissions.

## Learning Is a Verb

*Learning Is a Verb* (Reynolds, 2000), a book written by one of Fort Worth's partners at Texas Christian University (TCU), provides a scholarly background for the development of the new philosophical approach of the museum. Staff members reference their new ideas against the notion of good learning experiences described in the book.

For example, like many science centers, the museum has science demonstrations for visitors. However, Fort Worth has consciously moved from delivering a scripted performance to having conversations with observers about the phenomena. Staff are intentionally exploring the concept of "social learning" as it applies to the museum visit, hoping to discover from the interaction better ways to insure learning. According to one staff member,

*when learners engage in conversation about a phenomenon, they wrap language around their learning—they construct the concept and distill it to language in order to make it useful.*

Fort Worth invests in staff learning by bringing outside talent in to conduct professional development. Subsequent conversations among staff members continue the learning. Through this process the staff has adopted a slogan: "Focus on learning—it will change the world." They

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<sup>15</sup> State Systemic Initiatives were funded by NSF during the early 1990s as a large-scale, statewide reform strategy for mathematics and science.

note that this focus has changed the institution, and it has changed how the staff design and implement programs. Ultimately, they believe the focus on learning will translate to high-quality experiences for visitors.

Learning and relationships are the foundation for the mathematics programs presented at the museum. This case study will focus on the preservice teacher workshops conducted in partnership with Texas Christian University. The museum also has a preschool program and kits for classroom use that have mathematical connections. The exhibit floor is being reconceived to integrate science and mathematics and to reflect what staff has learned about learning.

## **Mathematics at the Museum**

### **Teacher Education**

#### ***Preservice Teacher Education***

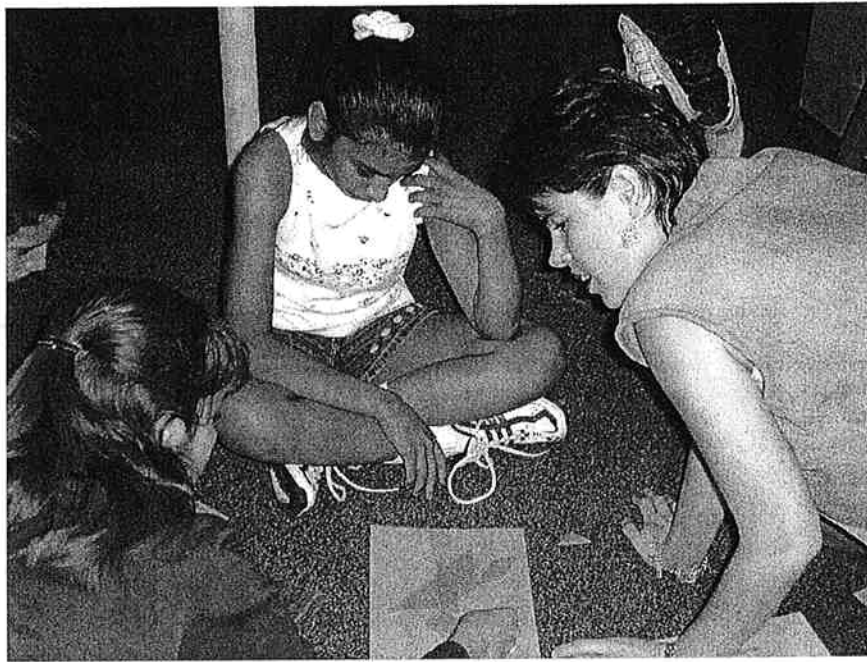
The *Preservice Teacher Education* program tells the story of museum transformation. As part of its transformation, Fort Worth intensified its relationships with local universities. In a pilot collaboration with Texas Christian University, the museum and the two TCU faculty members, Kathleen Martin and Sherry Reynolds, developed a program in mathematics education for college students enrolled in the teacher-certification program.

Mathematics educator Martin acquired a National Science Foundation grant to study inquiry and learning. She proposed bringing preservice teachers to the museum to work with visiting classes. Martin and Reynolds prepared the student teachers, while the museum arranged with the partner schools to bring in a class of students. The student teachers worked with small groups of children in a museum-organized lesson. The children were learning mathematics. The preservice teachers were learning about teaching.

The initial project began in 1993, and it has continued and expanded to include the University of Texas, Arlington. NSF no longer funds the core program, but the museum sustains it as an investment toward future business, using fees from the participating districts and other funds.

The museum invites local partner schools to bring students to the museum. These schools have a special relationship with the museum. The annual fee they pay guarantees that the partner schools' students have unlimited access to the museum. The museum also provides the schools with special opportunities for classes, such as those in which the student teachers work with small groups.

The university faculty members require their student teachers to go to the museum for preservice mathematics (and science) methods classes. Sometimes the student teachers work with the children on Piaget-type tasks. Most times the student teachers and children engage in what faculty members call "playful mathematics." The student teachers spend a significant amount of time teaching children and an equal amount of time reflecting on practice.



Grandfather Tang's story sets *Tangrams* into a multicultural context for mathematics and links math to literature.

The activity addresses the following NCTM Standards:

- Standard 3 – Geometry and Spatial Sense (items 3.3 and 3.4)
- Standard 6 – Problem Solving (items 6.1, 6.3, and 6.4)

The student teachers meet with the children in the Center for Science Learning, where each student teacher is assigned to work with a small group. Class begins when the Fort Worth staff person introduces the program and launches the activities for the day.

On the day of our site visit, the students were engaged in mathematics games: Tangrams, Mancala, and Magic Squares. The children rotated through the various activities, working with the student teachers. The task for the preservice teachers was, in part, to help the students understand the game and figure out the problem-solving strategies. At the same time, these fledgling teachers were observing how the students were learning the mathematics.

At the conclusion of the lesson, the children were brought together as a group to summarize their findings and insights. Anne Herndon, from the Fort Worth staff, conducted the lesson, making sure the underlying mathematics concepts were explored through the games. At the end, she dismissed the children and gave the podium to the TCU faculty. During the ensuing discussion, the preservice teachers described what they noticed and considered what it meant for them as future teachers in a school classroom.

At first, the novice teachers shared how their students figured out the problems they were given. They had been instructed to pay careful attention to how children responded to the games, to the challenge of finding solutions and winning. Shortly the conversation evolved to a discussion of mathematics.

While it was not clear from the discourse whether the teachers had a strong conceptual understanding of the mathematics, they recognized how powerful this way of mathematics learning is. One of the teachers said,

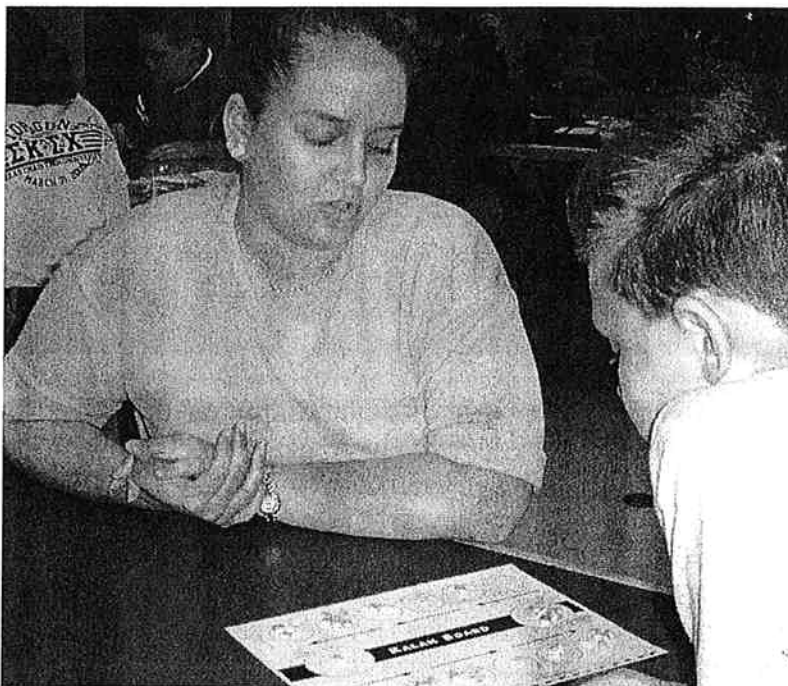
*If I had been taught this way I would not have wasted my time avoiding school. This kind of learning would be fun and I would know how to do the mathematics.*

There was consensus among the student teachers that they would teach this way once they had their own classroom. They discovered that the children later tried the same activities on their own and also found the youngsters engaged in other learning activities at the museum. The student teachers were thoughtful about using similar activities and materials in the classroom, because they could observe the way children responded. The student teachers were very positive about the whole experience and felt encouraged to think about teaching in new ways.

This preservice teacher found the boy using skillful strategies to defeat her in *Mancala*<sup>16</sup>. This strategy game develops accuracy in counting and the ability to plan ahead and solve problems. It is appropriate for a range of ages, from the very young (age 5 or 6) to adults. Discussions between student teachers and the children help both parties refine their mathematical thinking and learn to communicate.

The lesson help students understand these NCTM Standards:

- Standard 1 – Numbers and Operations (item 1.1)
- Standard 2 – Patterns, Functions, and Algebra (item 2.1)
- Standard 5 – Data Analysis, Statistics and Probability (item 5.1)
- Standard 6 – Problem Solving (item 6.3)
- Standard 8 – Communication (items 8.2 and 8.3)



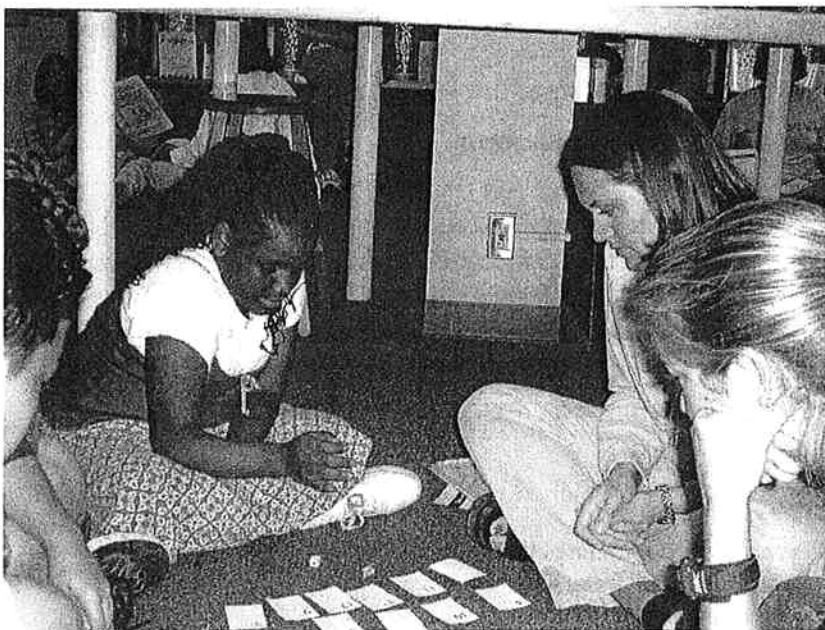
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<sup>16</sup> Called Mancala here, this game is also known as Kalah, the name used by the Lawrence Hall of Science.

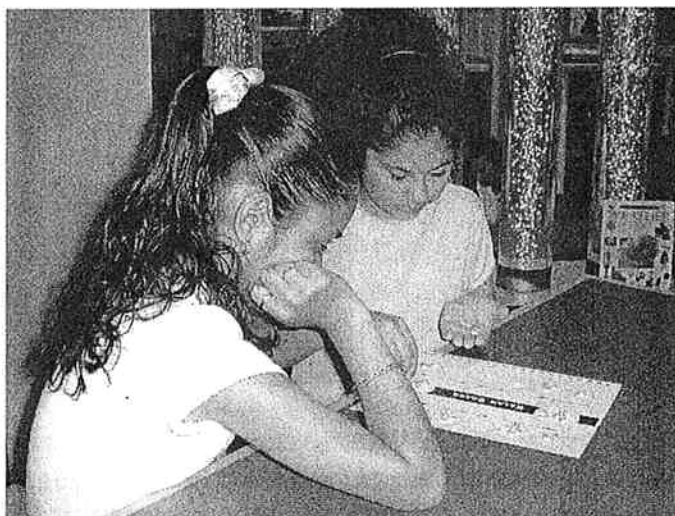
*Magic Squares* is a problem-solving activity that engages the learner completely.

This activity addresses

- Standard 1 – Numbers and Operations (items 1.1, 1.2, and 1.3)
- Standard 2 – Patterns, Functions and Algebra (item 2.1)
- Standard 6 – Problem Solving (items 6.1 and 6.3)



The photograph at right shows two of the children, who had participated in the preservice class at Fort Worth, playing one of the games they learned during the session.



Several of the students who had participated in the workshop with the student teachers set out to explore more mathematics. They decided to figure out what it would take to build a pyramid of glasses.

## Exhibits and Public Programs

### *Kits, Carts, and Collections*

Fort Worth has always had a teaching collection, which is used in its educational programs, as well as a permanent collection utilized for exhibitions on the museum floor. Now the museum is pulling items from the teaching collection, putting them into kits, and sharing them with teachers. Although for the most part there is no curriculum included, teachers (and home schoolers) can use the kits. Volunteers also use kit materials on “theme” carts, where they present objects, ideas, and interpretations for visitors.

As can be seen from this kit on the floor, Fort Worth is using authentic objects from its collections to enhance learning.



All kits and carts at Fort Worth are currently undergoing review in light of the museum’s new direction. At the time of the site visit, one hands-on program, *Multicultural Math*, had been discontinued, and during discussion staff presented it as a negative exemplar for the path the museum seeks. Staff felt that it neither constituted an “extraordinary learning experience,” nor linked with the NCTM Standards. One staff member articulated the essence of what they were seeking in a mathematics experience and explained the failings of the *Multicultural Math* kit:

*There is playfulness that comes from mathematics, but it comes from the experience. If the mathematics language comes from it naturally, as a useful tool to understand the experience, that is the best. That is the touchstone.*

*If the experience is real, then the mathematics should be the real stuff coming out of the experience. The frustration for learners within schools is that the problems are contrived and the mathematics is tedious. If the activity is too transparent in generating a mathematics skill, then it shows and it is boring.*

Fort Worth staff members want visitors to think about mathematics more broadly—as more than just doing arithmetic. The museum has struggled with what it means to do mathematics successfully. They continue to experiment with ways of providing experiences that lead to deeper understanding of mathematics principles. Once again Reynolds helps guide their thinking:

*Because of the nature of mathematics, which is relational, all mathematics is in the person, not the exhibit. The mathematics isn't in the exhibit; it is in the relationship with the phenomena in the mind of the viewer.*

*The person constructs all knowledge. The environment [exhibit] can trigger the construction of ideas. You can't assume it will deliver information, but the best exhibits disturb you about the ideas you hold. The question is, At what point is the disturbance solid enough that you can say you have done mathematics?*

### ***Exhibits with Mathematics***

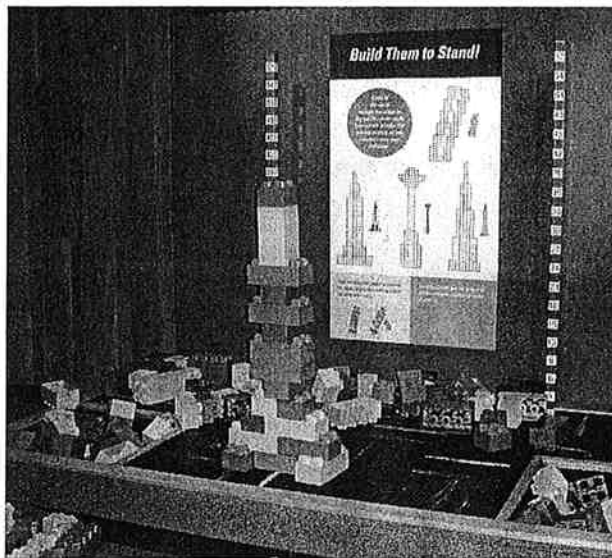
The exhibit designers at Fort Worth now acknowledge that visitors do not necessarily learn what a designer intends. People take away different things from an exhibit, based on what they started with and what they were seeking to know. Exhibits give an experience; the meaning-making depends on the individual. However, provocative exhibits and experiences that cause conceptual disequilibrium, may encourage individual reflection and additional investigation and ultimately trigger understanding.



The two Fort Worth exhibits shown invite the young visitor to explore ideas in mathematics. NCTM Standard 3 – Geometry and Spatial Sense, Standard 6 – Problem Solving, and Standard 10 – Representation are explored through computer or real-object exhibits.

The transition from displaying static exhibits to designing learning experiences has taken time. Collections are being used as hands-on objects for learning, and floor interpreters engage visitors in asking and answering questions. Each floor exhibit is observed for the kind of visitor interaction that suggests a deeper engagement with the ideas presented. The staff is examining

the exhibits to see that they meet the criteria of extraordinary learning environments and will drop or adapt those that do not fit the criteria.



*Build Them To Stand* is an exhibit that invites visitors to build towers. It addresses these NCTM Standards:

- Standard 3 – Geometry and Spatial Sense (items 3.1, 3.3, and 3.4)
- Standard 6 – Problem Solving (item 6.1 and 6.4)

*Dinosaur Dig* has children looking for bones. With an intentional mathematics extension to the activity, this exhibit could easily address these NCTM Standards:

- Standard 3 – Geometry and Spatial Sense (items 3.1, 3.2, and 3.4)
- Standard 4 – Measurement (item 4.1)
- Standard 5 – Data Analysis (items 5.1 and 5.3)
- Standard 9 – Connections (items 9.1 and 9.3)
- Standard 10 – Representation (item 10.1 and 10.3)



## Preschool Programs

Fort Worth is widely recognized for its preschool programs. Parents bring children to the preschool early in the day. During their time at the museum, the children are in classrooms filled with lots of free-choice activities.



In the photo at left, children move about the space, doing what they wish. But the staff has organized the space and set out enticing activities that enable children to have high-quality early experiences with both mathematics and science.

Counting out objects, distributing equal numbers for each child is an early learning activity. It addresses

- Standard 1 – Numbers and Operations (items 1.1 and 1.2)
- Standard 4 – Measurement (items 4.1 and 4.2)

Museum staff remain available to help children when necessary. At this station, children learn about making sound. Changing the rubber band's length changes the pitch. This builds understanding of

- Standard 2 – Patterns, Functions and Algebra (items 2.1 and 2.3)
- Standard 4 – Measurement (Items 4.1 and 4.2)
- Standard 9 – Connections (items 9.1 and 9.3)





A young girl begins the mathematics learning experience by playing with Legos.

The NCTM Standards connected here are

- Standard 3 – Geometry and Spatial Sense (items 3.1, 3.2, 3.3, and 3.4)
- Standard 4 – Measurement (item 4.1)
- Standard 6 – Problem Solving (items 6.1, 6.2, and 6.3)
- Standard 10 – Representation (item 10.2)

Children use scoops and measuring cups to pour sand into larger containers. The preschool experience with sand and containers helps young children understand the idea of capacity and conservation of volume and develop such understandings as it is not just the height of a container that determines how much it can hold.

NCTM Standards observed are

- Standard 1 – Numbers and Operations (items 1.1 and 1.2)
- Standard 3 – Geometry and Spatial Sense (items 3.1 and 3.4)
- Standard 4 – Measurement (item 4.1)
- Standard 8 – Communication (items 8.1, 8.2, and 8.3)
- Standard 9 – Connections (items 9.1 and 9.3)



## Lessons Learned

**Algebra is not the cause of mathematics failure; it is where lack of understanding becomes apparent.**

One of the most important lessons uncovered during the Fort Worth visit had to do with understanding mathematics learning. During the visit, the team met with TCU professor Sherry Reynolds, who provided insight regarding child development, teaching and pedagogy, and mathematics learning. One of the questions posed to Reynolds had to do with apparent mathematics failure at the middle school level. Based on her research in psychology and her observations at Fort Worth, the professor explained:

*We see children failing in algebra, but algebra is not the cause. Rather, algebra is the place where what you don't understand about mathematics and arithmetic becomes apparent.*

According to Reynolds' research, we can best improve understanding of algebra by improving children's understanding of arithmetic. She suggests that in the United States there is a specific problem with fractions, ratios, and proportions, but she notes that Swiss psychologist Jean Piaget said that an inability to do arithmetic is a uniquely American problem. Says Reynolds:

*If otherwise perfectly bright children can learn other subjects, but not mathematics, then something is wrong with how we are doing it.*

She is very interested in the active approach toward learning mathematics inherent in museum-type interactions. According to Reynolds, science centers can make potentially powerful contributions toward elevating achievement and understanding of critical mathematics concepts.

### **Taking risks and implementing new visions will build a stronger future for the museum**

Although the decision by Fort Worth to rethink its mission and direction caused staff to step back from traditional practices, they believe the risk will have enormous payoff. Establishing and holding to the standard of "extraordinary learning environments" will, in the long term, bring success. They believe it will stimulate deeper, longer relationships with partners and stakeholders and result in quality-of-life improvements for the community.

In the same way that notions of equity permeate Lawrence Hall and inquiry drives the Exploratorium, the focus on learning at Fort Worth is a thread of their corporate culture. Although the site-visit team viewed mathematics programs and products at the beginning of the process, it was clear changes had occurred. Conversations about exhibits and future plans reflected concern for deep and long-term learning, while programs were being modified to deepen the intellectual engagement of participants.

**Systemic changes in the museum and in public education require new roles and new relationships among partners.**

To change the system means that the role of each component and its relationship to other components must be rethought. Not only is Fort Worth going through a fundamental change internally; the museum is also seeking to change its role in the Texas education system. Stepping into a pivotal role as initiator of the Texas Informal Network, as part of the state's Systemic Initiative, resulted in a different view of what museums can contribute toward improved educational achievement. Moreover, this role altered how the museum viewed itself relative to the other informal "competitors." It stimulated the commitment to create partners and build relationships on a statewide level.

This view of cooperation rather than competition has resulted in much of the goal setting and role rethinking noted earlier. Fortunately, the museum leadership is willing to take the long view on systemic change.

In public education, systemic change addresses both mathematics and science achievement. Significantly, the museum is committed to continuing program and product creation in which mathematics and science are integrated. The network of relationships Fort Worth has built regionally and nationally will help the museum succeed.