Lawrence Hall of Science
www.lhs.berkeley.edu/
Lawrence Hall of Science

Equity and Mathematics

The Lawrence Hall of Science, in Berkeley, California, has long been recognized for its high-quality curriculum products—earning Lawrence Hall a stellar national reputation among K-12 educators. The science center came to occupy this niche in part because it is located on the University of California’s Berkeley (UC-Berkeley) campus and has been able to capitalize on this particular connection. However, Lawrence Hall, on its own merits, has been a magnet for intellectual and entrepreneurial talent, particularly in the field of mathematics education.

The purpose of this case study is primarily to describe the array of mathematics programs, products, and services at Lawrence Hall and to illustrate how mathematics came to be a major focus of a science center. The report describes the multiple external and internal forces that launched and sustained the initial mathematics effort and how new forces mediate the current programming. The long tradition of mathematics education places Lawrence Hall in an unusual position for providing leadership and/or material support for mathematics programming among science centers.

Mathematics programming began in the early 1970s, when a UC-Berkeley graduate student, Lucy Sells, noted that female students at the university were changing majors away from science because they were not prepared to do challenging mathematics. Alerted to the problem, Lawrence Hall staff member Nancy Kreinberg undertook her own investigation and found there were, indeed, fewer girls than boys coming to the science center to explore science and mathematics. Lawrence Hall then offered its first mathematics initiative, Math for Girls and Other Problem Solvers, which became in Kreinberg’s words:

...the seed for what has become a major focus at the Hall, encompassing workshops for teachers, conferences for adolescent women, and programs for working women.

Equity concerns launched mathematics programs at the Hall. Over nearly three decades, Lawrence Hall staff developed equity-based, rich mathematics curriculum, exhibits, public programs, and enrichment offerings for families and children, mostly under the umbrella of the EQUALS programs. Mathematicians, mathematics educators, and equity advocates found a welcoming, supportive, and entrepreneurial environment at Lawrence Hall in which to flourish and to find out what works educationally and financially.

With Math for Girls and Other Problem Solvers as the foundation, Lawrence Hall developed new programs and products and forged a strong reputation for high-quality mathematics and equity programming. Expanding Your Horizons, EQUALS, and FAMILY MATH emerged during the 1970s and early ’80s, but unlike other curricula from that era, EQUALS, and FAMILY MATH have

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4 Sells first introduced the concept of mathematics as the “critical filter” in her research report in The Science Teacher, 75 (1973): 28-29.
5 Throughout this document, the quotes are intended not to be a verbatim transcription of what was said, but rather to capture the essence of what was meant. Any errors in fact or meaning are the author’s and not the speaker’s.
flourished and continue to evolve. They bring revenue into the science center, are used by thousands of teachers and are marketed across the nation and internationally.

Equity remains a driving element of Lawrence Hall’s mathematics projects. Now as demographic changes rumble California, Lawrence Hall must adjust to an education reform agenda that sometimes moves laterally as much as forward. As external realities change, Executive Director Ian Carmichael has positioned Lawrence Hall to advance mathematics and equity by serving regional schools in new ways. Lawrence Hall is able to secure additional state funding (and visibility) for the science center, in part because of the strong equity thrust of earlier mathematics work. The ACCESS program, described on page 21, is the most recent iteration of the equity effort initiated by the Math for Girls project.

Challenges

Like many states, California faces the usual challenges to education: issues of teacher attrition, turnover, and inexperienced teachers. California also undertook a significant reform measure that lowered the teacher to student ratio to 1:20. Not surprisingly, in some circumstances, individuals were hired to teach without having the necessary credentials. California cannot ignore the issue of proper credentials, and so universities have been enlisted to help solve the problem.

California’s affirmative action proposition rocked the state and the nation by disallowing such policies in governmental agencies. UC-Berkeley faced recruitment issues in which its traditional supportive aid could no longer be provided to capable minorities. Anticipating the demographic shift in California, wherein minorities have become the majority, UC-Berkeley had to find new mechanisms to bring people of color to the campus—to ensure that the future leadership is receiving the education they need to discharge work capably.

California has a significant, content-specific education challenge—reconciling the demands of the revised State Mathematics Framework with the vision and goals of the NCTM Standards. In a document of more than 300 pages, the new California framework articulates more specific content details than the NCTM Standards, and lowers the grade level for which the Standards should be achieved. For example, one goal established by the state framework is for all 8th grade students to complete algebra. There is broad expectation that students will memorize mathematical algorithms and that teachers will not take the time to have students “construct” mathematical understanding. Funding from the state, which supports professional development, requires providers to ascribe to and support this view.

In that confluence of change-evoking forces, UC-Berkeley responded by adopting the Berkeley Pledge⁶, which commits the university to reaching out to minorities in the K-12 program. Because Lawrence Hall had existing inservice mathematics programs for teachers working with

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⁶ The Berkeley Pledge is “designed to fulfill the university’s historic promise to maintain diversity while preserving excellence and to provide the best education to all of California’s diverse student populations, particularly those whose opportunities are limited because they are financially or educationally disadvantaged.” For more information refer to http://www.chance.berkeley.edu/spledge
minority and underserved populations, the University engaged the Hall as an active partner in achieving the outreach goals.

In mobilizing to respond to changing external realities, Lawrence Hall undertook a critical review of its operating structure. A new vision of Lawrence Hall—being in service to schools and in support of school system changes that help students achieve—places a stronger emphasis on reaching out to public education, especially those schools with significant minority populations. Staff now works more with public education offerings, doing customized workshops and programs, and less with curriculum development.

In the realm of mathematics, Lawrence Hall models a way to serve the community, elevate K-12 achievement, and retain its identity as an informal learning institution. Most of the high-caliber mathematics products from the past are still in use, and a powerful new relationship between the schools and the science center is emerging.

Mathematics at Lawrence Hall

Curriculum Products

Math for Girls and Other Problem Solvers, Lawrence Hall’s first foray into mathematics, helped girls understand mathematics and develop positive attitudes toward the discipline. It was, in part the answer to these questions: How do we get girls involved with mathematics? How do we help girls see that mathematics is the foundation for many career choices—that without it, options decrease significantly?

At the early stages of Math for Girls, when young women were asked about career choices, their answers reflected societal images of the early 1970s. For example, girls considered glamour choices like modeling careers and could see little use for extend academic work in mathematics.7 Because young teens, on their own and without proper guidance, often make choices with long-term negative consequences, especially in mathematics, doors to the future get closed prematurely. Math for Girls essentially said, “So, you are thinking about dropping math? Well, say goodbye to these career choices....”

The next phase developed in partnership with Mills College in Oakland. The program Expanding Your Horizons, cofounded by Lawrence Hall’s Nancy Kreinberg and Lenore Blum of Mills College, augmented the career and mathematics connection. Teachers, together with middle and high school girls, attend a full-day conference, hearing from women who use mathematics daily in their work and participating in hands-on workshops.

Lawrence Hall’s keystone program, EQUALS, is built on the success of working with a specific population and addresses the challenges experienced by underrepresented students—minorities and females—in achieving success in mathematics. FAMILY MATH came about when

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7 Early in the work on mathematics, EQUALS staff would ask students about what they were interested in. The responses at first revealed overwhelming interest in “glamorous” activities like modeling or being a sports superstar. By the end of the year, job choices were more balanced.
administrators and teachers requested strategies for family members to use in helping their children learn mathematics and develop "can do" attitudes. Customized teacher workshops provide curriculum and teaching strategies designed to help all children learn.

The concern for equity and achievement that framed the original direction for these programs, has not ameliorated. If anything, the need for accessible\(^8\) mathematics is greater, not just for students, but for their teachers as well. \textit{EQUALS, FAMILY MATH}, and the teacher professional development remain in tune with the changing demographics and populations using the products. Most of the curricula have been translated into Spanish, and a few are available in other languages as well.

\textit{EQUALS Investigations}

The five \textit{EQUALS Investigations} units were designed to approach mathematics from a problem-based model. For middle school grades, \textit{EQUALS Investigations} promote a vision of mathematics in which students collaborate to solve interesting and somewhat complex problems. Each of the units takes one or more of the core strands from the NCTM Standards and sequences activities to challenge thinking and build concepts. Students are expected to collaborate because children learn in different ways and benefit from the thinking of others.

The units are rigorous and conceptually complex—reflecting current research on how the human brain is stimulated to solve problems (Sprenger, 1999; Wolfe, 1996). Students are visually or verbally clued into the critical mathematics connections they must make. Inherently, there is recognition that success may take a lot of time and thought, and teacher comments convey a "stick-with-it tone."

The activities within a unit build sequentially, and teacher commentaries in the margins of the page convey what really happens for students during each segment. Although within-unit activities are sequenced, \textit{EQUALS} does not recommend a particular sequence of the units themselves. Each unit focuses on a particular concept from the middle school NCTM Standards. Table 1 on the following pages reflects the correspondence of units with the Standards.

\(^8\) "Accessible" refers to an approach that is developmentally appropriate, connects to real world examples that make sense to students, and provides enough description or experience that concepts are understood. Symbolic representation and manipulation are secondary to conceptual understanding.
Table 1. Correspondence of *EQUALS Investigations* with NCTM Standards

<table>
<thead>
<tr>
<th>NCTM Standards</th>
<th>EQUALS Investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Growth</td>
</tr>
<tr>
<td>1. NUMBER AND OPERATION</td>
<td></td>
</tr>
<tr>
<td>1.1 Understand numbers, ways of representing numbers, relationships among numbers and number systems</td>
<td>X</td>
</tr>
<tr>
<td>1.2 Understand the meaning of operations and how they relate to each other</td>
<td>X</td>
</tr>
<tr>
<td>1.3 Use computational tools and strategies fluently and estimate appropriately</td>
<td>X</td>
</tr>
<tr>
<td>2. PATTERNS, FUNCTIONS, AND ALGEBRA</td>
<td></td>
</tr>
<tr>
<td>2.1 Understand various types of patterns and functional relationship</td>
<td>X</td>
</tr>
<tr>
<td>2.2 Use symbolic forms to represent and analyze mathematical situations and structures</td>
<td>X</td>
</tr>
<tr>
<td>2.3 Use mathematical models and analyze change in both real and abstract contexts</td>
<td>X</td>
</tr>
<tr>
<td>3. GEOMETRY AND SPATIAL SENSE</td>
<td></td>
</tr>
<tr>
<td>3.1 Analyze characteristics and properties of two- and three-dimensional geometric objects</td>
<td>X</td>
</tr>
<tr>
<td>3.2 Select and use different representational systems, including coordinate geometry and graph theory</td>
<td>X</td>
</tr>
<tr>
<td>3.3 Recognize the usefulness of transformations and symmetry in analyzing mathematical situations</td>
<td></td>
</tr>
<tr>
<td>3.4 Use visualization and spatial reasoning to solve problems both within and outside of mathematics</td>
<td>X</td>
</tr>
<tr>
<td>4. MEASUREMENT</td>
<td></td>
</tr>
<tr>
<td>4.1 Understand attributes, units, and systems of measurement</td>
<td>X</td>
</tr>
<tr>
<td>4.2 Apply a variety of techniques, tools, and formulas for determining measurements</td>
<td>X</td>
</tr>
<tr>
<td>5. DATA ANALYSIS, STATISTICS, AND PROBABILITY</td>
<td></td>
</tr>
<tr>
<td>5.1 Pose questions and collect, organize, and represent data to answer those questions</td>
<td>X</td>
</tr>
<tr>
<td>5.2 Interpret data using methods of exploratory data analysis</td>
<td>X</td>
</tr>
<tr>
<td>5.3 Develop and evaluate inferences, predictions, and arguments that are based on data</td>
<td>X</td>
</tr>
<tr>
<td>5.4 Understand and apply basic notions of chance and probability</td>
<td></td>
</tr>
</tbody>
</table>

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Table 1, *cont.* Correspondence of *EQUALS Investigations* with NCTM Standards

<table>
<thead>
<tr>
<th>NCTM Standards</th>
<th>EQUALS Investigations</th>
<th>Growth Patterns</th>
<th>Remove Rulers</th>
<th>Telling Someone Where to Go</th>
<th>Flea-Sized Surgeons</th>
<th>Scatter Matters</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. PROBLEM SOLVING</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>6.1 Work with problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>6.2 Formulate, represent, abstract and generalize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6.3 Use wide variety of strategies</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>6.4 Reflect on their mathematical thinking</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7. REASONING AND PROOF</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7.1 Recognize reasoning and proof</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>X</td>
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<tr>
<td>7.2 Conjecture</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7.3 Make mathematical arguments and proofs</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>7.4 Use various types of reasoning and methods of proof</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8. COMMUNICATION</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8.1 Communicate with others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8.2 Express mathematical ideas coherently</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8.3 Consider the thinking and strategies of others</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>8.4 Use the language of mathematics</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>9. CONNECTIONS</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>9.1 Use connections</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>9.2 Build mathematical ideas on one another</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>9.3 Recognize mathematics in contexts outside of mathematics</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>10. REPRESENTATION</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>10.1 Use representations</td>
<td></td>
<td></td>
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<td></td>
<td>X</td>
</tr>
<tr>
<td>10.2 Develop repertoire of mathematical representations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>10.3 Use representations to model and interpret</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Funding for the development of *EQUALS Investigations* came from NSF to the Investigations Mathematics Curriculum Project at the Office of the President of the University of California. The funding allowed for two individuals from outside Lawrence Hall to author the publications, which were then reviewed, edited, and published under the *EQUALS* program umbrella. This organizational structure reflects the kind of collaboration increasingly found at Lawrence Hall.

Evaluation and research on Lawrence Hall’s mathematics programs is incomplete. While controlled, refereed research was conducted for some of the individual projects or products during the development, for others it was not. There has been no research on the *EQUALS* program as a whole; however, the *EQUALS Investigations* materials were trial-tested in six local schools and then in schools across the nation. Outside researchers have studied the impacts of some of the materials, but the research is not comprehensive.

**FAMILY MATH**

Equity and access issues impelled the *EQUALS* team to consider alternative strategies to support mathematics achievement. Under the *EQUALS* program umbrella, other curricular products developed. Perhaps the best-known spin-off product has been the *FAMILY MATH* program, which seeks to involve more parents in their children’s mathematics education. *FAMILY MATH* relies on the target parents’ deep concern for their children and according to staff, depends on

> the [target] parents’ willingness to see that their children have a chance to do things that they [the adults] never had the opportunity to do.

Sometimes parents, as much as their children, lack an understanding of what is required for a quality mathematics education. In a study funded by the National Action Council for Minorities in Engineering (NACME) (Leitman, Binns, & Unni, 1995), researchers found that 93 percent of parents do not know that the class choices middle school students are making have significance for their high school coursework and subsequent career options. Furthermore, the study noted that while minority students have reported a higher percentage of interest in being a scientist, they drop out of mathematics in greater numbers (Leitman et al., 1995). The *FAMILY MATH* program encourages students to take more mathematics and provides guidance for parents in counseling their children and helping them with math.

During *FAMILY MATH* programs, the staff reserves time for parents to talk with the instructor, to raise questions and find out the importance of specific topics and content. A particular concern for parents is ensuring that their children have facility with arithmetic. Parents tend to push for what they recognize as mathematics and typically push formal and abstract thinking too early. Parents want numbers—remediation in arithmetic—for their children, since that is their vision of mathematics. Yet, most parents’ experience of this approach to mathematics—the manipulation of representational symbols—was odious and hateful. *FAMILY MATH* instructors work to broaden the parents’ view of mathematics.

In many respects mathematics education has changed since the time parents were in school. Mostly this is a consequence of continued research on how children learn mathematics. *FAMILY MATH* instructors found that the most effective sessions begin with something familiar to the parents, such as number activities, but as lessons unfold they include a wide range of

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mathematics activities to entice the children. The challenge lies in presenting the activities so that parents recognize and understand the underlying mathematics content.

An activity may start with a number problem, where parents can see the mathematics, but the activity also has an element of play to entice the children. For example, one activity involves rolling dice. For children this is “luck,” but the underlying mathematics is probability. Play helps build the understanding of mathematics and demonstrates that mathematics is more than numbers. Such sequenced learning helps parents construct a different vision of mathematics—one that is more fun and develops understanding. Comments from parents reflected the benefit of the FAMILY MATH experience for them:

I finally get what is going on in school. Before this, understanding what teachers wanted was hard.

I get it now! I’m finally getting the mathematics I never got before.

Sometimes the mathematics is not explicit, and instructors have the responsibility of helping parents see the connections and assuring them that they can support their child’s learning, even if their own mathematics knowledge is limited. For example, the focus for FAMILY MATH: The Middle Years is algebra and number sense. Activities allow families access to algebraic reasoning, help family members see the mathematical thinking in the activities, and lay a foundation for formal algebra. Parents are taught to ask questions that direct attention to possible solutions: Can you tell me what the problem is about in your own words? Would it help to draw a diagram? Did you check your arithmetic?”

FAMILY MATH attempts to minimize barriers to mathematics learning and capitalize on unexpected opportunities. Language differences often mediate against student achievement and parental involvement. FAMILY MATH makes it possible for students to have a choice of language9 for instruction, and lessons are modeled in two languages. Using the language most familiar to people minimizes this barrier to achievement.

Involving parents often provides an unexpected increase in instructional capacity of a lesson. A FAMILY MATH instructor described a “teachable moment” that generated from class participants:

In a class on measurement, we involved kids tracing hands or feet on paper, and cutting those “tools” out and using them to measure other things. One parent asked, “Since you are doing measurement, should my kid know how to use a ruler?” Other parents jumped in and shared stories and thoughts about useful connections and what they thought would be appropriate.

FAMILY MATH was, and is, an extremely popular program. Lawrence Hall needed to respond to the demand for more inservice workshops. Using a trainer-of-trainers dissemination strategy, Lawrence Hall expanded the number of FAMILY MATH delivery sites to include museums, school

9 FAMILY MATH is now available for Spanish-, Swedish-, and Chinese-speaking audiences. Portuguese is anticipated for the future.
districts, state and county departments of education, universities, and community organizations. The trainer-of-trainers model permits programmatic growth, as it maintains program integrity, builds a network of experienced and talented teachers, and provides Lawrence Hall with a point of contact within a community.

The *FAMILY MATH* books are available for sale through the Hall's website and can be ordered individually, although their major use still occurs in workshops. There are currently more than 500,000 copies of *FAMILY MATH* for elementary and middle school in use across the nation. The publications are responsive to concerns heard from parents and educators. Since school culture is not always inviting to families, the newest publication, *FAMILY MATH: The Middle School Years*, includes a section on ways to help children make appropriate decisions and gives tools for parents to use in understanding the education system.

**Mathematics in Public Programs**

Public programming is usually the bread and butter of a science center. The draw of visitors, school groups, and families secures the financial foundation for most institutions. Lawrence Hall, like other science centers, makes use of available floor space for exhibitions and public events. However, Lawrence Hall makes public offerings work for them in other ways as well. In mathematics, three examples tell fascinating stories.

**GEMS**

Lawrence Hall pioneered engaging hands-on lessons for the visiting public. At some point, staff recognized that their public program activities had never been documented, so they set out to document and publish sets of activities generated for public programs, weekend enrichment activities, festivals, assemblies, and school programs. *Great Explorations in Math and Science (GEMS)* began when people started stringing the activities together to see which could be easily adapted for the classroom. *GEMS* is now probably the most widely used school enrichment curriculum.

*GEMS* guides are organized by topic, with a conceptual theme or story line (e.g., a mystery) that ties each guide into a package. Activities are basically a collection of interactive tabletop stations that engage students in a variety of experiences but are not developmentally sequenced for learning. When *GEMS* is used in a classroom, students are encouraged to work with a partner and debrief with their teacher about the ideas learned.

The success of *GEMS* increased its usage in schools, because it brought hands-on learning to children and integrated mathematics and science meaningfully. *GEMS* now has 70 publications (60 teacher guides) and is taught in after-school classes, summer camps, and multisession courses. A large network supports delivery and distribution of *GEMS*, but like other Lawrence Hall products, requires a site to have a *GEMS* Associate, someone trained on the products. There are now more than 40 *GEMS* leadership sites—mostly located in teacher resource centers.
Although the GEMS books are extremely popular, their basic nature, the context of their origin, and their structural organization makes them appropriate as enrichment, but not as school curriculum. When queried about alignment with national standards, staff noted that the products stand philosophically with the NCTM Standards and the National Science Education Standards (NSES).

*Math Around the World*

*Math Around the World* started as classroom activities that were later gathered in a *GEMS* publication. Lawrence Hall’s exhibit department took it on and created a number of mathematics exhibits that now occupy the space near the science center’s entrance. The sequence of photos from *Math Around the World* shown in the following pages conveys the exhibition’s potential and the interactive nature of its mathematics activities. The majority of the exhibits are games, which permit the visitor to have fun and learn mathematics content that aligns with the NCTM Standards. Also since the games are taken from the *GEMS* guide of the same name, visitors have the option of extending their play at home.

*Hex* is a recent invention created by Piet Hein and introduced at the Niels Bohr Institute for Theoretical Physics. The game requires the players to think offensively and defensively, as each person tries to create a pathway of tessellating pieces from one side of the board to the other. *Hex* corresponds to the NCTM Standard 3rd – Geometry and Spatial Sense for using visualizations and spatial reasoning to solve problems. It also matches Standard 6 – Problem Solving, since players must use a wide variety of strategies to be successful.

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APPENDIX, page 116, provides the reader with an abbreviated chart of NCTM Standards developed by the author for use with this project. They are based on the draft version of the revised Standards. Any discrepancies noted between the chart and the now-published *Principles and Standards for School Mathematics, 2nd Edition* (2000) may reflect a revision of the draft or an error in transcription by the author.

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In the *Games of Alignment* exhibit shown above, visitors place colored markers onto a game board and try to block their opponent’s pieces from moving. The exhibit addresses NCTM Standard 2 – Patterns, Functions and Algebra, and Standard 6 – Problem Solving.

The photograph to the right shows *Kalah*, the oldest-known continuously played game. Players move beans (or beads or stones) around the game board seeking to claim as many beans as possible.

*Kalah* addresses NCTM
- Standard 1 – Numbers and Operations;
- Standard 2 – Patterns, Functions and Algebra
- Standard 6 – Problem Solving
Game Sticks is a Native American game, sometimes used for gambling, in which the objective is to obtain all the counters. The game can be used to help students achieve several NCTM Standards:

- Standard 1 – Numbers and Operations
- Standard 2 – Patterns, Functions and Algebra,
- Standard 5 – Data Analysis, Statistics, and Probability
- Standard 6 – Problem Solving.

Magic Squares is a number game in which the object is to arrange numbers in cells so that they add up to the same total, regardless of whether the computation is done by row, by column, or diagonally.

There is an obvious link to Standard 1 – Numbers and Operations, but the game also introduces algebra in a fun way. Players must use logic and apply patterning skills.
Another game of strategy, NIM is used to introduce game theory (one of the branches of discrete mathematics), since the players actually need to construct a model to look at possible outcomes. The goal is to have a strategy that will let you always win by removing the last piece.

The NCTM Standards addressed by this challenging game are

- Standard 1 – Number and Operation (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 (items 6.2 and 6.3)

The photograph to the left shows site-visit team member Melissa Thompson, from Pacific Science Center, exploring how NIM works.

Young girl tries NIM on her own.
**MATH RULES!**

Another exhibit at Lawrence Hall focuses on mathematics. That exhibit, located in proximity to the *Math Around the World* exhibition, is called *Math Rules!* It does not have a teacher’s guide, but seems as engaging as the games from *Math Around the World*. The activities in *MATH RULES!* were designed to reinforce concepts from NCTM Standard 2 – Patterns, Function, and Algebra. The following photographs display a few of the exhibits.

*MATH RULES!*
Balancing Act

*MATH RULES!*
Trading Towers
Teacher Education in Mathematics

ACCESS (Alliance for Collaborative Change in School Systems)

Many of the curriculum products identified in the earlier sections rely on teacher workshops to disseminate the materials. In this section we focus on the most recent and probably most intensive teacher education program from Lawrence Hall. It is a model that requires significant outside funding, but it strongly illustrates Lawrence Hall's vision of working with schools—as reflected in the following sentiment expressed by staff:

_Schools can't solve all the societal problems...but if we don't address mathematics achievement in school, then we simply replicate the gatekeepers._

ACCESS is a professional development program for middle and high school teachers and a form of service learning for graduate students in mathematics. The program also provides professional development and technical assistance for school counselors and administrators. ACCESS aims to increase the minority and underrepresented populations in college—clearly sanctioned by the Berkeley Pledge. Structurally, ACCESS is a fluid set of relationships, involving Lawrence Hall staff, University of California faculty and graduate students, and selected local school districts.\(^{11}\) Of course, as with any successful program, benefits accrue to all stakeholders, with each party getting something of value.

The participating districts contract with Lawrence Hall and assign a teacher to work with the ACCESS team. Monday through Thursday, the ACCESS teaching staff work full days within targeted schools. They offer workshops in the morning and spend the rest of the day working in specific classrooms. They also confer with individual teachers on specific problems encountered while teaching the subject.

Teachers in the schools receive broad support, not just in the area of mathematics content, but ACCESS also hopes to help teachers address equity and access issues for their students. The general approach is to improve teaching practices, including the use of new assessments. Most effort is focused on helping teachers examine curriculum, learn new teaching strategies, and meet the State Framework for Mathematics.

ACCESS coordinators from Lawrence Hall are assigned to four or five schools, where they spend up to 30 hours working with teachers, counselors, and administrators. On Fridays, ACCESS teachers and coordinators meet at Lawrence Hall to address concerns that emerged during the week. During the weekly sessions, the providers learn leadership skills, techniques for collaboration, and relationship building. At the same time, the meetings provide needed reality checks for the work, as well as time to remember the purpose and vision of the program.

ACCESS is also a peer-teaching program. ACCESS sends graduate students to work as instructional teaching assistants in the K-12 schools. The graduate students strive to make mathematics accessible for the middle and high school pupils, serving as tutors and classroom

\(^{11}\) Oakland, Emery, San Francisco, and West Contra Costa Unified School Districts
aides. The graduate students, being close in age to the secondary school students, provide guidance and a support system for high school students considering career or college options. The college students are given training on how to work with school kids and are mentored throughout the program.

The graduate students benefit from this experience of teaching. In the competitive world of higher education, access to academic positions depends on presenting a portfolio of accomplishments. But while research remains the significant selection factor for positions in higher education, many new professors will be placed in teaching colleges rather than research-focused institutions. Some ACCESS graduate students enjoy being a member of a K-12 staff and decide to go back and get a teaching credential. As one graduate student observed:

\[ \text{The experience gained through ACCESS is unlike anything else my [peers] have. I have learned things not available to me from the rest of [my] program.} \]

Simply put, the graduate students benefit from knowing more about teaching and being able to point to successful experience in teaching.

When ACCESS employees are asked about the intent of their work, they respond “we want children to think about college, even if they don’t enter.” This answer is core to Lawrence Hall and is about equity, which is deeply embedded in Lawrence Hall’s work in mathematics. Lawrence Hall and UC-Berkeley are committed to helping school districts understand and push for public school students’ achievement in mathematics.

With ACCESS, Lawrence Hall created guidelines for placing students in mathematics courses. The program gives assistance to school counselors, helping them to understand the scope of mathematics and the sequence of coursework. As a result, students receive better advice, specific recommendations, and support in making appropriate choices. Administrators are included in addressing the socio-cultural issues that interfere with students’ achievement. All school personnel are encouraged to consider changes in school culture and organizational structures that may create positive environments in which children might flourish.

Funding support for the program comes from a patchwork of sources. Districts contract with Lawrence Hall for the program, using funds provided by the state. State funding goes to the university to support graduate students and fund the teacher certification and professional development programming. Lawrence Hall collaborates with the education faculty, houses the ACCESS program, and monitors its implementation. Lawrence Hall receives Berkeley Pledge grant money to operate the program. Other funding comes from matching efforts. Recently one of the partner districts said they would fund one additional teacher (beyond the FTE count) to be in the teaching labs within each of the high schools.

Documentation of effectiveness is necessary for continued funding. There is an evaluation coordinator who is now documenting results. When ACCESS was launched in 1980 with the Oakland School District, there were only a few staff members serving a limited number of teachers. The program has grown to 15 full-time staff and now partners with three school
districts, 27 elementary, middle, and high schools, and 15 collaborative programs, in addition to its core work.

Lessons Learned

There is much to be learned from an institution that has blazed a trail in mathematics. Lawrence Hall has produced a number of high-quality, widely accepted products. These products are well researched and grounded in best practices. Because they are aligned with NCTM Standards, they can serve as a framework by which other institutions can create programs and exhibits.

Mathematics expertise is important for developing quality products in this discipline.

Among the lessons learned, the importance of knowledgeable and talented staff is paramount. While science centers need not have mathematics PhDs on staff, they need access to competent people (staff or advisory) with extensive backgrounds in mathematics and mathematics education who can help translate content into experience. The depth of content understanding mathematicians bring to the enterprise ensures that the activities are more likely to develop deep ideas in mathematics and less likely to convey misconceptions. Because science centers attract scientists (and generalists) who may or may not be facile with mathematics learning, being assured of substantive, quality mathematics may depend on having committed outside advisors.

Lawrence Hall has access to UC-Berkeley faculty and academic talent from other Bay Area institutions, as well as having staff members with extensive mathematics experience. This struck the site-visit team as a significant advantage. Connections with UC faculty help to ensure content expertise and a strong advisory function. But Berkeley is not an isolated, university community; it also has a surrounding population that is intellectually supportive of research and development. Moreover, as a state agency Lawrence Hall can offer salaries that are attractive to the community pool of intellectual talent. A further benefit of being on the UC-Berkeley campus is having access to graduate students. Lawrence Hall is a built-in opportunity for students to do graduate research or to find employment before or after graduation.

Ultimately, Lawrence Hall has invested in high-caliber staff, which means that the Hall has deep capacity to deliver high-quality programs—a fact not lost on its federal, state, and corporate, funders. Grant-funded curriculum-development projects flourish at Lawrence Hall, in part because the Hall's purpose, supportive atmosphere, and available office space encourage collaborative exploration of educationally sound and financially supportive endeavors.

Using equity as a lens for mathematics seemed to lead to richer, more complete learning experiences.

Looking at mathematics through the lens of equity made for an effective strategy for developing discernibly richer learning experiences. As a gatekeeper discipline for many careers and college-program choices, mathematics must be accessible to young people, both in terms of opportunity and the quality of activities. Keeping their site firmly fixed on equity has provided Lawrence Hall the additional lens on mathematics that helped insure quality products that would work for
all learners. The defining question seemed to be: What mathematics do children need to know in order to be successful? That is a different question from what mathematics can a science center offer and it seems to push toward deeper levels of learning.

Young people need to realize the importance of a mathematics education and acquire the conceptual understandings of higher-level mathematics. Breaching the barriers to higher-order mathematics is part of the overall reform effort in mathematics. Whether the barriers are deficits in skills or conceptual understandings, self-definition, or cultural perspectives and language obstacles, product research and development should target achievement for all students.

Start small, do what you already do well, and grow products from that foundation.

Lawrence Hall did not jump into large-scale mathematics programming. The process was more inquiry-like. An initial question launched Math for Girls and lead naturally to other equity questions and an expansion of offerings. It suggests that other science centers should start small and grow the programs based on the successes of their experiences. Of course, many of the Lawrence Hall programs offer workshops that could seed the endeavors at new science centers.

The philosophy of learner-centered experiences is a pervasive, subtle, and complex orientation at Lawrence Hall that might be defined as their “institutional culture.” Current research on learning and best practices in mathematics is present in virtually every curricular product or workshop given by Lawrence Hall under the umbrella of the EQUALS program. A philosophical underpinning of constructivist learning permeates student activities, the directions given to teachers, and the exhibits. The flavor of reform is discernable within the activities and is more directly communicated in the Preface and Notes in EQUALS Investigations. It is this vision of mathematics and robust learning, developed over nearly 30 years, that makes Lawrence Hall of Science a flagship science center for mathematics.

Build partnerships with the formal system for support and for reaching new K-12 audiences.

Lawrence Hall made a decision to build connections with the formal education system—a decision that may or may not be attractive to other science centers. Curriculum development and programs targeting schools define the linkage, but the ACCESS program is the strongest and deepest connection with schools yet. It is a deep connection and a strong commitment, since it requires funding support for staff to be in school buildings, and a complicit agreement to abide by and acknowledge the NCTM and California Standards. In short, Lawrence Hall—in mathematics at least—has allied itself with the formal program and its fortunes will rise and fall with the schools.

On the positive side, the ACCESS relationships have brought in additional funds to Lawrence Hall through the University’s Berkeley Pledge. There is a line item for the program in the state budget, with the money flowing to the science center through the university.

Lawrence Hall has been successful in mathematics in part because the staff listens to its constituents. They consider suggestions from teachers, parents, and caregivers and respond with
creative, workable ideas. For example, *FAMILY MATH* is a direct outgrowth of concerns raised by teachers and principals who didn’t know how best to involve families in the changing mathematics curriculum. At one point, a school district administrator said:

*Parents are asking for ways to help their children at home, and my teachers are trying to answer that, but teachers are so busy they can’t find the time and resources to help.*

By listening to these concerns, Lawrence Hall crafted an enormously successful program.

**Since NCTM Standards and State standards may not match, a science center must consider how to reconcile the different expectations.**

California is a microcosm of the political differences that find expression in how we expect teachers to function and children to behave. The recently legislated California mathematics framework is somewhat parallel with the NCTM Standards, but there is a distinction between them in how the material is delivered and used by students. The staff members, who have long-term professional affiliations with NCTM, must reconcile state expectations with NCTM philosophical perspectives. The same challenge may apply to other states as well.